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Third Conference on Advanced Pollution Control for the Metal Finishing Industry Held at Orlando Hyatt House Kissimmee, Florida on April 14-16, 1980

American Electroplaters' Society, Inc.
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Third Conference on Advanced Pollution Control for the Metal Finishing Industry

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"The Third EPA/AES Conference on Advanced Pollution Control for the Metal Finishing Industry" was held in Kissimmee, Florida, on April 14-16, 1980. The primary points of the gathering were: The status of EPA's wastewater and solid waste regulations, and both EPA's and industry's research efforts to effectively address the ramifications of these regulations. Air pollution and energy recovery, financial pollution control alternatives, and centralized treatment of metal finishing residuals were also discussed at the conference and reports of this work appear in these proceedings. These proceedings contain the presentations made by representatives of various EPA regulatory groups affecting the metal finishing industry, as well as presentations by parties actively addressing research and development in this same industrial area.

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Third Conference On Advanced Pollution Control For the Metal Finishing Industry

PRESENTED AT:
ORLANDO HYATT HOUSE, KISSIMMEE, FL
APRIL 14 - 16, 1980

Co-sponsored by:
- The American Electroplaters' Society
- The United States Environmental Protection Agency

Industrial Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

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Foreword

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

These proceedings cover the presentations from the "Third EPA/AES Conference on Advanced Pollution Control for the Metal Finishing Industry." The purpose of the conference was to inform industry on the range and scope of research efforts underway by EPA and others to solve the pressing pollution problems of the metal finishing industry. It is hoped that the content of this proceedings will stimulate action to reduce pollution by illustrating approaches and techniques high-lighted by the wealth of excellent papers presented at this conference. Further information on these projects and other metal finishing pollution research can be obtained from the Nonferrous Metals and Minerals Branch, IERL-Ci.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

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INTRODUCTION

"The Third EPA/AES Conference on Advanced Pollution Control for the Metal Finishing Industry" was held in Kissimmee, Florida, on April 14 - 16, 1980. This broad scoped colloquium was jointly designed by the American Electroplaters' Society and the U.S. Environmental Protection Agency's Nonferrous Metals and Minerals Branch. The primary objective of this conference was to continue the dialogue established at the First EPA/AES Conference (1978) and strengthened at the Second EPA/AES Conference (1979) between key members of the EPA and the metal finishing industry. The proceedings, contained herein, of this Third Conference reflect the primary points of the gathering: the status of EPA's wastewater and solid waste regulations, and both EPA's and industry's research efforts to effectively address the ramifications of these regulations. Air pollution and energy recovery, financial pollution control alternatives, and centralized treatment of metal finishing residuals were also discussed at the conference and reports of this work appear in these proceedings.

The program of the conference was broken into six segments: wastewater, regulation and research; solid waste, regulation and research; an exchange of viewpoints between members of the government and industry; air pollution and energy recovery, regulation and research; centralized treatment as an alternative to on-site treatment of wastewater and solid waste residuals; and concurrent sessions addressing detailed inquires on the pollution problems and finiancial alternatives available to the metal finishing industry. Since attendees of the first and second conferences placed extreme emphasis on wastewater and solid waste, the first two segments of the Third Conference were structured to provide conference attendees with a detailed understanding of the potential impact of current and future regulations in these two important environmental areas, as well as the research being conducted to address wastewater and solid waste pollution problems. Key EPA officials, representing EPA's water and solid waste regulatory offices and research office, described the procedures by which EPA prepares and promulgates regulations and conducts research activities having direct impact on metal finishers. Industrial participants described, in various papers, examples of current and potential solutions to wastewater and solid waste pollution problems.

The third segment, entitled 'Exchanging Viewpoints" was conducted during an evening session. A panel comprised of EPA officials and industry representatives opened the floor to a free discussion in order to permit EPA and industry to commonly and clearly understand those research needs considered to be of paramount importance. This objective was fulfilled as the needs became evident during frank discussions between the attendees and the panelists.

The fourth segment of the conference discussed air pollution regulations and research activities, as well as the energy recovery potential available to the metal finishing industry. Besides a discussion of current and pending air pollution regulations by an EPA official, various EPA research projects structured to produce cost-effective technologies and approaches to the primary metal finishing industry's air pollution problems were described.

Centralized treatment, the fifth segment, was discussed during the entire final session of the conference. Papers on this viable alternative to on-site treatment of wastewater and solid waste were presented by industrial representatives from the United States. Centralized treatment as practiced in West Germany since 1964 was described by an esteemed colleagues from the Federal Republic of Germany. EPA's research program on centralized treatment was also discussed in detail.

A group of concurrent sessions comprised the sixth segment of the conference. Individual groups of speakers representing the various sessions of the conference provided detailed commentary on his or her area of expertise. Attendees of the conference were permitted to attend the various detailed concurrent sessions depending upon their interests. A special room was established for individual attendees to receive detailed information on pollution control financial alternatives.

This conference, attended by more than 600 persons interested in the environmental problems faced by metal finishers, was considered an extraordinary success. The principal purpose of the conference, to continue a fruitful dialogue between industry and EPA, was achieved. The high-priority research needs of the industry were identified and solutions to pressing problems are being sought—some jointly—by EPA and AES.

The proceedings are published here in order that the important material presented at the Conference can benefit as many people as possible interested in solving the intricate problems inherent in metal finishing processes. These proceedings contain the presentations made by representatives of various EPA regulatory groups affecting the metal finishing industry, as well as presentations by parties actively addressing research and development in this same industrial area.

The EPA and the AES are pleased to have cooperated in this mutual endeavor which has improved communications and which should foster continued research resulting in sound technical solutions to the environmental problems of metal finishers.

George S. Thompson Jr

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Chief
Nonferrous Metals & Minerals Branch, EPA

J Howard Schumacher Jr

J. Howard Schumacher, Jr.
Executive Director
American Electroplaters' Society, Inc.

EPA Welcome to the Third Conference On Advanced Pollution Control For the Metal Finishing Industry

William A. Cawley*

I would like to extend to you EPA's "welcome" to this Third Conference on Advanced Pollution Control for the Metal Finishing Industry. In addition, I offer a special thanks to Howard Schumacher and his staff, to Mike Murphy and to other AES members who have worked diligently to make the conference possible. We hope our efforts are successful in providing you with an understanding and an awareness of EPA's regulatory and R&D activities impacting the metal finishing industry.

We in EPA view this conference as a timely and cost-effective tool for us to obtain the metal finishing industry's evaluations of and recommendations for our ongoing and planned programs. Consequently, this conference is a critical activity in EPA's metal finishing R&D program. This year we again solicit your participation and comments after each presentation and particularly at the Tuesday evening discussion session. Members of my staff who are responsible for the development and implementation of the metal finishing R&D program and who are present at our Conference are George Thompson, Chuck Darvin, Fred Craig, and Anil Mehta. George and his people will be actively soliciting your comments and reactions during this conference's discussion periods and through informal contacts. We intend to compile this information and distribute it to you for comment along with the conference proceedings.

The major goal of the R&D efforts is to develop and evaluate pollution control methods that are broadly applicable to the metal finishing industry, that present cost-effective options for meeting regulations, and that minimize or eliminate intermedia transfer of the pollution problem.

At our first EPA/AES conference we attempted to bring to you the status of EPA's total efforts in air, water, solid waste, and toxic substances which are likely to impact your industry. Last year we focused on the Agency's water and solid waste programs which we feel will have the greatest impact in the near term. This year, our primary emphasis is on water and solid waste with lesser emphasis on air, financial alternatives and centralized treatment.

I personally would like to encourage you to critically evaluate the ongoing and planned R&D activities in view of the major R&D goal I have stated, and to provide your candid comments on each project and the overall program direction. Your participation is essential to the success of the conference and to EPA and the industry's efforts to control pollution from the metal finishing industry.

Once again, I am glad you are here and hope that I have the opportunity to meet many of you during the next three days.

---

*William A. Cawley
Deputy Laboratory Director
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"Status of AES Research"

J. Hyner*

Even before our nation became conscious of the effects of pollution upon our environment, the AES had sponsored research projects with the goal of rendering harmless the effluents and solid waste of the metal finishing industries.

Of the nine AES research projects currently active, five are directed towards solving some aspect of pollution. Of the five pollution oriented projects, two are co-sponsored by the EPA.

I'll review the reason for choosing each active pollution project and bring you up to date on the current status of each.

PROJECT NO. 48

Title: *The Effect of Anions on the Precipitation of Heavy Metal Ions from Electroplating Wastewater*

Site: Columbia University; Project Director: Dr. Huk Y. Cheh; Co-sponsored with the EPA

All who have effluent purification systems operating have learned that theoretical hydroxide precipitation of heavy metal ions is not always obtained. You have learned that even though today you may be meeting your standard for copper, or zinc, or any other metal, tomorrow you cannot do better than 5 ppm. We long suspected that assorted anions often interferred with and prevented complete precipitation of the heavy metals. The purpose of Project No. 48 is to determine which anions commonly used in plating interfere with complete precipitation, by what mechanism does interference occur, and most important, how do we control or neutralize the interferences so that theoretical precipitation can occur, allowing us to successfully meet EPA standards. Although authorized a year ago, the project is just getting started since Dr. Cheh was on sabbatical leave for a year. Isidore Cross, a past president of AES is chairman of the project committee. In talking to him this morning I learned that his committee is complete and ready to start getting the project underway. Phase I is expected to be completed some time during the coming year.

PROJECT NO. 49

Title: *The Effect of Electroplating Wastewater Sludge as an Admixture on the Physical Properties of Concrete*

Site: Manhattan College; Project Director: Dr. Robert Spinna; Not co-sponsored with the EPA

Purifying our wastewater is now a common practice in the plating industry and, within the next few years, should be universal. The problem of what to do with the tons of metal salts removed from the contaminated rinsewaters has become pressing. Most of the metals have been removed in the form of insoluble hydroxides. What shall we do with them? The ideal solution, of course, would be to remove the metals from the sludge and reuse them. This is technically possible with current knowledge. However, until much more tonnage accumulates, it is not really economically feasible. Even though a few hundred tons of sludge may be a tremendous amount to a plater, it is very little to a refiner, so that of necessity very few refiners would be needed in the United States. The cost of transporting sludge great distances is tremendous and, at current metal prices, makes refining uneconomical.

What can we do with our sludge for the next few years - for the time it takes all shops to get on stream and maybe enough sludge is generated to make area refineries economically feasible, if ever?

We have known for several years that the Japanese and Europeans have encapsulated and immobilized sludge in concrete. Cement is alkaline, insoluble, and theoretically could serve to keep the metal hydroxides from dissolving and leaching back into the environment. Our project was not set up to repeat the work of the Japanese and Europeans, whose interest was only in finding a place to safely dispose of sludge without concern for the strength and properties of the altered concrete. We are interested in the concrete as well as in giving the platers a safe disposal site in almost every city in this country. If incorporation of some sludge in the concrete does not alter the properties of the concrete, every batching plant theoretically becomes a disposal site. The head of our project, Dr. Spinna, is a professional engineer whose specialty is concrete and construction. Associated with him are chemists whose specialties are applied to leaching and the chemical structure. Tomorrow, Dr. Mahony, who has been conducting leaching studies using radioactive tracers will report on his results.

Tests to date on the strength and properties of sludge-modified-concrete show that the incorporation of sludge containing 1½ - 2% solids into concrete to replace water does not appreciably alter the physical properties of cured concrete, and the concrete is so insoluble that leaching of metals is in the order of parts per billion—completely safe to the environment.

This project has not been co-sponsored by the EPA. That agency was a bit skeptical in the early days of the project. Now that the first two phases of study have been so successful, we will again submit a proposal for further

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work to the EPA and to the Office of Solid Waste. Hopefully this time around, the AES, the EPA, and Portland Cement Association will be able to work together. We desperately need safe, convenient disposal sites for our sludges generated by the clean up of other effluents.

PROJECT NO. 51

Title: *Immiscible Rinsing of Plating Solutions*

Site: United Technologies Research Center; Project Director: Dr. Jordan Kellner; Not co-sponsored with the EPA

The best way to control pollution is to close the loop and not discharge plating waste, most of which comes from rinsing after plating. During the last few years reverse osmosis, electrodialysis, Donnon dialysis, ion exchange and evaporation have been both researched and employed to capture and reuse the plating solution rinsed off the plated parts. Incidently, more of the closed loop type of methods were researched under EPA grants, some with AES cooperation. All have been used to some extent. All the above processes require expensive equipment and skilled attention, which often makes the process economically unattractive, even though technically satisfactory.

If we had a non-aqueous immiscible solvent that would rinse off the plating solution and then allow the rinsed solution to either sink or rise, the solution could easily be returned to the plating tank for reuse without further treatment. This may be a long shot, but if successful, an ideal way to save solution and solve a pollution problem. In research to date, twenty-five different solvents were mechanically shaken to react the solvent with chromium plating solution—a solvent would be useless if it rinsed well but contaminated the chromium bath. Of the twenty-five initially tested, five were chosen for continuing tests because of low reactivity with chromium solution, low cost, toxicity and boiling points. The chosen solvents also represented different chemical structures consisting of saturated, long-chain hydrocarbons, saturated, branch-chain hydrocarbons, an aromatic ether and an aromatic hydrocarbon. Tests with the five solvents are now underway, and some results should be available by July, 1980.

PROJECT NO. 53

Title: *Development of a Reactor to Eliminate Cyanide in Electroplating Effluents*

Site: Ontario Research Foundation; Project Director: Al Cadotte; Not co-sponsored with the EPA

Chlorine oxidants and peroxides are almost universally used to destroy cyanides. They are very expensive and sometimes dangerous to handle. A cheaper, technically sound method to destroy cyanides used in the metal finishing industry would be universally welcomed.

It's been known for many years that cyanides can be destroyed by hydrolysis when heat and pressure are applied.

Experiments at the Ontario Research Foundation have indicated that heating a cyanide-containing solution, for example, a copper cyanide plating bath, in a sealed container to 210° C, approximately 450° F, for only a few minutes will effectively destroy the cyanide.

Based on its laboratory work, Ontario Research is building a flow-thru reactor of standard stainless steel pipe to determine the feasibility of using this principle in practice.

I am personally tremendously enthusiastic about this project. I believe that it will be successful and that within a relatively short time will be the means of saving metal finishers thousands of dollars annually and, at the same time, eliminating cyanide very effectively from our effluent.

PROJECT NO. 55

Title: *Sludge Characterization*

Site: Centec Corporation; Project Director: Mr. Paul Minor; AES/EPA Cooperative Agreement

The EPA required more information about the leaching characteristics of electroplating sludges, and with the information gained, it would have the basis for establishing safe, segregrated disposal sites for solid waste. It also required a rapid on-site test of sludge so that a disposal site operator could quickly test a batch of sludge sent in for disposal and determine whether or not it could safely be dumped at the disposal site.

Twelve different sludges, from twelve plating plants covering most of possible types of sludges produced by the plating industry, have been collected, leached and analyzed. I believe that when the testing program is completed, results will show that metal hydroxide sludges from plants with satisfactorily operating effluent systems can safely be placed in segregated landfill sites with no potential harm to the environment. Analysis showed that the only soluble metal ions were in the interstitial liquid and that the amount of leached metal was so minute that leaching of the interstitial water in the rains would yield concentrations below levels acceptable for discharge.

Future work will research more of what happens to the interstitial water and will also investigate models for a satisfactory disposal site.

The sludge characterization and concrete projects will be covered in more detail later in the program.

Status of EPA Research

George S. Thompson, Jr.*

INTRODUCTION

Fourteen months have past since our Second EPA/AES Conference. During this time period, many things have happened affecting the metal finishing industry. Not only has the cost of raw materials and energy skyrocketed, but environmental regulations have been - or are shortly to be - established for the air, water, and solid waste pollution generated by the industry. Pretreatment regulations for electroplaters were promulgated in September of 1979. Revised BAT will be proposed in the near term. Regulations for solid waste generators should be out before the end of this month. Regulations specific to solvent degreasers and other sources of volatile organic compound (VOC) emissions will shortly be established.

Where does research fit into such a complex and fast moving situation? Our purpose is well established - to provide, in a timely way, cost-effective technologies and approaches through research, development, and demonstration that will meet or surpass the requirements established by air, water, and solid waste regulations. For those of you who were not present at the Second EPA/AES Conference or who have not seen the Second Conference "Proceedings," I represent the research arm of EPA - EPA's Office of Research and Development (ORD). My Branch, the Nonferrous Metals and Minerals Branch (which during the past 14 months has received a new name resulting from a reorganization) is part of one of ORD's field laboratories - the Industrial Environmental Research Laboratory - located in Cincinnati, Ohio. Now in our fifth year, we are chartered to conduct R&D on the air, water, and solid waste discharges from a number of industries including the mining and milling of nonfuel minerals; the smelting and refining of nonferrous metals; the manufacture of glass, ceramics, cement and lime; and, of course, metal finishing and fabrication.

Recent Achievements and Research Goals

The last 14 month period has seen an increased understanding of our metal finishing research goals related to solid waste and an overall attempt to accelerate our efforts to establish more timely answers. Before I describe these goals, allow me to list our achievements since we last met:

- Publication of three reports for broad dissemination:
  - "Environmental Pollution Control Alternatives: Economics of Wastewater Treatment Alternatives for the Electroplating Industry"
  - "Summary Report - Control Technology for the Metal Finishing Industry - Evaporators"
  - "Summary Report - Control and Treatment Technology for the Metal Finishing Industry - Sulfide Precipitation
- Completion of data package for Mechanical Products and Electrical/Electronic Products Industries
- Completion of the EPA/AES Cooperative Agreement on Metal Finishing Sludge Characterization
- Completion of EPA-Inhouse Metal Finishing Sludge Stabilization Study
- Completion of Solvent Degreaser Evaluation Project
- Completion of Computer Program for Quantifying Energy Savings From Increased Operating Lower Explosion Limit (L.E.L.) on Paint Curing Ovens
- Completion of First Two Phases of Centralized Treatment Program
- Input to EPA's Office of Water Planning and Standards (OWPS) on Structure and Detail of "8-City Seminar Series for Electroplaters"
- Publication of R&D Reports

The current goals of our metal finishing research program and our plans and methods to meet these goals follows.

Goal I - Complete Investigations on Inplant Changes

Many metal finishers have stated that such in-plant changes as water conservation steps, reducing chemical usage, etc. are "old hat" or "common knowledge." This knowledge is, of course, new to some of you, but certainly not to all of you. I have quickly become aware of the significance of in-plant changes and how these changes have an effect on wastewater and solid waste pollution generation and the economics of treatment and/or disposal. Our efforts to identify in-plant changes; to measure their effectiveness in reducing wastewater volume, wastewater pollutant loading, chemical usage, and sludge generation; and to ascertain the associated costs to implement these in-plant changes continues. Ed Roof or Varland Metals Services will be describing the various in-plant changes used at his job shop during this afternoon's water session. I would also like to make reference to Clarence Roy's presentation at the Second EPA/AES Conference (published in "Proceedings") which discussed in-plant changes and their impact on sludge generation.

---

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Whether you already have wastewater control (i.e., concentrating techniques) and/or treatment techniques in-place or are now "shopping around" for solutions, please go back to your metal finishing processes and evaluate the impact of utilizing in-plant changes. Hopefully, we will have a detailed report on in-plant changes reviewed and published by August, 1980.

Goal II — Provide Wastewater Control and Treatment Technologies That are Easy to Operate, Non-capital Intensive, Do Not Produce a Sludge, etc.

This goal is (and may continue to be) one of our most difficult goals to achieve; many parties in both the public and private sectors have attempted to achieve this goal over the past decade with only partial success.

Our approach to achieving this goal changed 14 months ago. Previously, we sought novel ideas and then funded or co-funded laboratory-scale, bench-scale, pilot-scale, and full-scale demonstrations. Some of our previous research efforts were stopped due to some form of failure or limitation of a technical or economic nature. Others proved successful. The primary reason for changing to a different approach was TIME.

Wastewater regulations and guidelines have been established for portions of the metal finishing industry; regulations and guidelines for the remainder of the metal finishing industry will be set in the near future. The compliance period for some metal finishers (e.g.: electroplaters discharging to Publicly-Owned Treatment Work: [POTW's]) has started and this goal must be achieved soon to have impact.

Our new aproach to achieving this goal is three-fold:

- Clearly identify existing solutions. Identify their applications, as well as their limitations. Document, by evaluating full scale applications, their capital costs and operating and maintenenace costs as well as operating problems. Broad dissemination is used to "spread the word" as far as possible so that the largest number of readers will benefit from our evaluations. Our "Alternatives Report" and "Summary Report on Evaporators" (described under "achievements" above) are examples. We have a similar summary report on ion exchange nearly ready for review and publication. We have also completed several major efforts on soluble and insoluble sulfide precipitation; a summary report on this treatment technology has been published and copies of this full color report are available at the EPA table. A decision was reached several months ago to prepare a brief status report on reverse osmosis, since this control technology does have some excellent applications. We do not plan to perform further RD & D on this technology.
- Complete RD & D on promising approaches that have excellent potential. Several technologies fall into this category. One is an electrochemical reactor which we have been demonstrating at Varland Metal Services. Ed Roof, who is discussing in-plant changes this afternoon, will also describe the status of the demonstration on cadmium, zinc cyanide and chloride, copper cyanide, chromium, and nickel plating wastewaters. We are also completing a demonstration of electrodialysis. Last month, we funded an effort to develop an anionic membrane for Donnan dialysis; this technology is very promising and if such a membrane can be successfully developed, we will enter into a full-scale demonstration.
- Evaluate "Emerging Technologies" for wastewater control and/or treatment. At our Second EPA/AES Conference, I explained portions of what became our Emerging Technology Program. This program is currently being implemented. The purpose of this program is simply stated. We are not aware of numerous wastewater (this program also addresses air and solid waste, but current emphasis is on wastewater) control and treatment technologies and alternatives. This program should maximize our awareness. An "Awareness Bulletin for Metal Finishers" will, on a bimonthly basis, canvas numerous trade (and related) publications and provide to the reader a synopsis of findings. Copies of the first "Awareness Bulletin" are available at the EPA table for review and comment. Besides the bimonthly Bulletin, the Emerging Technology Program is structured in three phases: (1) Identification of candidate emerging technologies, usually through received telephone calls and other forms of correspondence, and prioritizing of these candidates for "third party evaluation" based on established prioritizing criteria; (2) Detailed or "third party" evaluations of the highest prioritized technologies requiring field visits and possible sampling; and (3) Dissemination of results by means of a Summary Report publication. The technologies we are looking for are those that are either operational on a very small scale (one or two plants) or are close to commercialization and, in both cases, are potential national solutions to aiding us in reaching our goal.

As I did at the Second EPA/AES Conference, I solicit any "Emerging Technologies" that you may be aware of so that we can consider them for our ongoing program.

Goal III - Provide Guidance to Upgrade Existing End-of-Pipe Wastewater Treatment Facilities and to Improve the Design of New Facilities.

Several research activities are either completed or nearly completed that should allow us to achieve this goal. One activity has just been initiated that will hopefully address methods of upgrading existing end-of-pipe systems for better wastewater pollutant removal and sludge formation.

For new end-of-pipe neutralization/precipitation systems, a Manual of Practice has been prepared and has undergone extensive review. Publication of this manual is forecasted by July, 1980. Even though it is not a design manual, it has been prepared to provide guidance to metal finishers (and other industrial users who employ conventional neutralization/precipitation technology) when faced with the need to purchase and/or fabricate such a system. Sludge is also addressed in this manual.

Our recently published Summary Report on Sulfide Precipitation describes soluble sulfide polishing techniques that can be added to existing hydroxide systems to achieve better effluent quality. Similarly, the Summary Report on Ion Exchange, which is currently in first draft form, provides detail on the application of ion exchange for polishing conventional end-of-pipe treatment technology effluents.

A new research activity has just been initiated which resulted from the recently completed EPA/AES Sludge Characterization project. Current plans for this new activity call for field visits back to the electroplating plants visited during the initial 3-phase project. The end-of-pipe wastewater treatment systems at each plant will be scrutinized to determine possible "upgrading" steps, such as removing certain influents, using different neutralizing chemicals and/or flocculants, etc. Screening of possible changes will be conducted in the laboratory and verification of the most promising will be field demonstrated. Since the quality and quantity of the sludge generated by the wastewater treatment system is directly related to the design and/or operation of this system (conclusion resulting from EPA/AES Sludge Characterization study), this new research activity could provide methods for improving effluent quality, chemical usage, and sludge quality and quantity. More detail on this new project is provided under Goal IV.

Goal IV - Provide Solutions to the Metal Finishing Industry's Sludge Problem.

The approach to achieving Goal IV is quite complex. The EPA/AES Cooperative Agreement on Metal Finishing Sludge Characterization has been completed. Ken Coulter will provide more detail on this project tomorrow. The AES and EPA have jointly defined a follow-on laboratory/field project. This project has been partially funded this year; we hope to complete the funding of this project next year through another cooperative agreement with the AES.

We have just initiated a project on documentation of current practices in "sludge usage/waste exchange." Our investigation will cover the United States, Japan and Western Europe. The finding and documenting of several environmentally safe uses of sludge may lead us to additional uses and may also prove to be part of our goal.

We are currently establishing an inhouse program to determine the best metallurgical techniques for cost effective recovery of metals from single and multiple-metal sludges. The concept is simple and justified - the sludges being investigated are hazardous sludges due to their toxic nature; their toxicity is caused by their metal content. Therefore, the metal content must be reduced to a degree that makes the sludge non-toxic. Two product streams will be produced - recovered metals and nonhazardous sludge. Anil Mehta of our staff is responsible for this inhouse effort and will explain his approach on Tuesday.

Another potential solution which may enable us to reach our solid waste goal is Centralized Treatment. This alternative would not only prove to be technically and economically advantageous for metal finishing wastewater, but also for sludge. As witnessed from our investigation of West German Centralized Treatment, segregated retention areas for metal hydroxide sludge have been established for waste exchange and metal recovery. As the volume of "retained" sludge grows, metals recovery becomes more economically viable and the Centralized Treatment concept is the best collection and "retention" alternative available.

One last R & D activity, which is now in its second year, is a combination of Centralized Treatment and metals recovery from cadmium-bearing sludge. This is a cooperative agreement with the International Lead/Zinc Research Organization. The approach under investigation is the collection of metal finishers' cadmium-bearing sludges and transport to a primary zinc smelter (cadmium is a byproduct of primary zinc production) and the subsequent recovery of cadmium values in the zinc production circuit.

Goal V - Provide Centralized Treatment to the Metal Finishing Industry as a Technically Sound and Economically Viable Alternative to On-site Wastewater Treatment and Sludge Disposal.

Our metal finishing Centralized Treatment Program is now in its 13th month. Fred Craig, of my staff, and I originally envisioned this program as a four phase effort, with the third phase calling for demonstration and the forth phase evaluating and disseminating the results of the demonstration. Fourteen months ago, Fred Craig described this four-phase effort and some attendees commented that our program on Centralized Treatment was dynamic, but not timely enough for metal finisher's needs. What we have now, after having completed the first two phases is sufficiently detailed information on Centralized Treatment to act as a catalyst for you to implement the concept. Not enough can be said about this alternative for metal finishers - the findings of the first two phases of this program are very enlightening and, in summary, I believe that the necessary tools are now available for you to determine if Centralized Treatment can provide a partial or total solution to your wastewater and/or sludge problem. Note on your conference program that the entire Wednesday morning session is devoted to Centralized Treatment; I urge you to attend this session - it will prove to be quite enlightening.

Goal VI - Provide Techniques for the Control of Volatile Organic Compound (VOC) Emissions

The use of solvents in the metal finishing industry, whether in solvent degreasers or as part of a paint formulation, leads to the atmospheric discharge of VOC. Some metal finishing operations are major sources of VOC.

We currently have a number of research activities, including some field evaluations and full-scale demonstrations, focused toward the above goal.

One major activity on solvent degreasers is essentially completed and Chuck Darvin of my staff will report on the important findings of this study during the Tuesday afternoon "Air Pollution and Energy Recovery Session." Chuck provided interim status of this activity at both the First and Second EPA/AES Conferences. If you currently use degreasers, or plan to use them in the future, I strongly suggest that you listen to Chuck's presentation - especially since the New Source Performance Standard for this VOC source will soon be proposed.

We are currently fabricating a scrubber, which uses surfactants as the scrubbing media. This summer, we will test it at our inhouse facility followed by field testing at a Cincinnati firm. If you operate a company in the Cincinnati area that discharges VOC from metal coating operations and would like to test the surfactant scrubber at your plant, please contact us.

We have set up a microprocessor at the EPA Conference display table. The demonstration from this microprocessor is part of a joint project with the Department of Energy. The overall goal of this joint effort is to monitor and control the lower explosion limit (LEL) of paint bake oven atmospheres in order to safely increase the LEL. By increasing the LEL from 5-10% to 25-50%, significant fuel savings will result and VOC destruction can be economically practiced with primary and secondary heat recovery. The controlling mechanism will be an inexpensive microprocessor. A presentation on this joint EPA/DOE project will be made during Tuesday afternoon's air session. If you are interested in the economic incentives resulting from increasing your curing oven's LEL, please visit our display table and witness the economic calculations. If you have the necessary data on your curing oven(s), please provide this data to us and the economic calculations will be made for you. We are hoping that this display will give you the incentive to seriously consider the objectives of this project; we are also currently looking for a demonstration plant.

Recently, we initiated a "fact finding" study on fugitive VOC emissions from paint application. If you are aware of any novel techniques for collecting fugitive VOC emissions from this source, please contact us.

Several other metal finishing/VOC activities are nearly complete, such as our environmental/energy evaluation of a gas recirculation system. Some of these projects address new coating formulations that are low in solvent content.

In the near term, we plan to conduct RD & D on "low temperature incineration." If you have any research ideas on this subject, please contact us.

Goal VII - Disseminate All Pertinent Findings. Ensure the Highest of Quality in these Findings

The metal finishing industry has more plants, both large and small/captive and job, than any other industrial category. When pertinent findings are made, they must be broadly disseminated in order to have visability and, in-turn, impact.

We have thus far published three full color reports for broad dissemination that address wastewater control and treatment technology for metal finishers (solid waste is also covered, but to a lesser extent). Two of these three, published last June, have already been distributed to over 10,000 individuals and companies both in the U. S. and abroad. These reports are part of our Summary Report Series for Metal Finishers. Two more reports will be published to temporarily complete this Series: one on "Ion Exchange" and the other on "Emerging Technologies". We plan to prepare others, especially when pertinent solid waste/sludge findings are made.

We also publish reports for most of our research projects. A complete list (as of January 1979) of these publications is contained in the Second EPA/AES Conference "Proceedings".

Besides dissemination through written materials, we feel that workshops, seminars, and conferences are important tools, especially for 2-way communication. Our First and Second EPA/AES Conferences have afforded us the opportunity to not only understand your problems, but to also gather your research ideas.

The second part of this goal is to achieve high quality output. Again, this Conference allows us to describe our current and planned activities and our major areas of emphasis. As stated in this year's (and last year's) "EPA's Opening Remarks", EPA's Office of Research and Development views this Conference as an excellent source of critique and constructive criticism. The quality of our products can never exceed the quality of our program goals and the approaches to achieve these goals.

We attempt to have our "final drafts" reviewed and commented on by as many interested parties as possible from both the public and private sectors. If you would like to provide constructive criticism of any of the activities described in this presentation, please contact us. Lastly, I offer our products to the metal finishing industry's trade magazines for "peer review."

During the past nine months, we have been deeply involved with other EPA Offices and industrial representatives in structuring what we term the "Eight City Seminar Series for Electroplaters". This series, which should start during the last week in August, is designed to explain technological wastewater and solid waste control and treatment alternatives, as well as discussions on financial alternatives available to finishers. For more information on this seminar series, please contact my office or Ms. Francis DeSalle at (202) 426-7874.

In conclusion, I have attempted, during this presentation, to describe the goals of EPA's air, water, and solid waste metal finishing research program. I solicit any comments you may have on these goals and on our approaches to achieve them.

Status of Wastewater Regulations

Robert B. Schaffer*

I appreciate the opportunity to spend this time with you every year. As in our previous two conferences, I have some new information to provide to you. I consider these descussions with you to be a very important part of my job. Although getting the regulations out on time is important, dealing with the regulated public through interchanges and discussions is also a very important aspect of providing good regulations. As with last year and the year before, I am going to continue to give you a preview of what is to come. I will also discuss the final pretreatment guidelines as they were promulgated last fall. Also, I will tell you about all the changes we have subsequently made to the promulgated regulations.

As you may know, the pretreatment regulations, after they were promulgated, were challenged by the National Association of Metal Finishers. The main issues brought forth have been discussed in a continued spirit of cooperation for accomplishing good regulations. We believe that the problem areas have been resolved and the necessity to proceed with litigation has been eliminated. We are currently in the process of putting together the results of those negotiations and I am going to discuss, unofficially at least, the changes to the regulations, which will be proposed shortly. If they are finalized without significant change after a proposal and comment period, our agreement is that the litigation will be dropped.

The most significant changes will be in the revision of the total cyanide limitation. The total cyanide limitation will increase from 0.8 to 1.9 milligrams per liter. Second, we are going to eliminate the 30 day limits. In their place, we will establish four day limits. This change was made to eliminate the possibility of extensive and burdensome monitoring requirements. The new cyanide numbers were taken from monitoring data and, even though they differ numerically, still describe the performance of the technology.

We are also going to remove the requirements for monitoring that were included in the promulgated pretreatment regulations, primarily because of the difficulty in specifying good monitoring requirements for all unique situations that exist. The requirements themselves, will not be in the categorical standards but will be included in the general pretreatment regulations as a guide to those who will be implementing a pretreatment program.

Finally, and of significance, the Agency has agreed not to propose more stringent pretreatment regulations for several years. The reason, which I'm sure is obvious to you, is to give a target that is going to stand still for a while. Because it takes time to get the necessary equipment purchased, shaken down, and installed and because you need some flexibility in financing, the Agency has agreed to let these regulations stand for several years. Don't ask me what several years means, I don't have the answer to that question. Generally, however, a period of five years is not an unreasonable expectation. The direct dischargers with a permit have that amount of time. I think that kind of philosophy is going to follow through in this particular instance; however, *no commitment has been made on either side. Let me make that clear.*

There are, of course, still questions associated with the electroplating pretreatment regulations and the general pretreatment regulations that Steve Schatzow mentioned earlier in his keynote speech. These regulations are in the process of being modified.

We continue to be concerned over the impact on municipal sludges, the severity and the magnitude of that impact, and how to determine whether it is a good idea to have heavy metals in municipal sludge. Within the Agency, there have been a few different philosophies and conflicts which we finally referred to as "big piles" and "little piles." Some feel that it is very important to have very tight control over toxic materials and that they should not be indiscriminately discharged into the municipal systems to contaminate municipal sludges, a practice that would prevent their disposal in ways that are potentially beneficial or more economical. On the other hand, others believe that these materials are more manageable if kept in municipal systems and in municipal sludges, because then you would have a better handle on where they are. You would know that the sludge is within a particular jurisdiction and who has the responsibility for proper disposal of the solids. The issue is still under discussion, and I expect it will be for a while.

We initiated a study on municipalities which I refer to as the 22nd industry. BAT is looking at toxics from 21 industries. We decided that there might be another one - a pretty good size one - that is the municipalities. So we initiated the study to look at the occurrence and fate of toxic pollutants in municipal treatment systems. We have completed about 40 to 50 percent of that study and have the results back on 30 percent of it. We tried to select representative cities that have properly operated treatment systems that are achieving the secondary treatment requirements for municipal discharges. We tried to pick plants that had different types of treatment technologies installed, such as trickling filters, activated sludge, etc. We also tried to select plants with differing geographical locations and with different amounts of industrial inputs.

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The results so far have been very interesting. With no surprise, we find that the heavy metals are consistently removed in the municipal systems, up to the point where they are concentration limited (i.e., solubility limited). But assuming that a significant amount of metals enter the plant, the level that is discharged is reasonably independent of the type of industrial or non-industrial city that is being sampled. The effluent concentration of heavy metals from municipal treatment systems is pretty much the same whether it is from a "dirty city" (i.e., one having a lot of industrial discharge to be treated) or from a more domestic residential city where the industrial contributions are relatively low. There is however a small, but identifiable pass through in the effluent from cities with a higher influent concentration. We are also finding that the organic materials that are entering the POTW's are also removed to a very high degree. Part of our reason for summarizing some of the initial data is to see what kind of impact this will have on the credit policy that is included in the general pretreatment regulations. To see what kind of consistent removals we might find, it turns out that, in highly industralized cities, there are slightly higher removal efficiencies than in nonindustrial cities. This generalization is very broad. For most of the heavy metal pollutants that are in the influent that you would be discharging and that we are concerned over, a rough average of about 50 percent removal efficiency through the municipal system has been initially determined. This percentage varies somewhat; but from metal to metal, from city to city, it looks like 50 percent. By pooling all of the data we have, we will have the necessary confidence for determining credits. Much of this information, as well as additional work of determining the effect of toxic pollutants on the municipal treatment systems, will be presented at the Water Pollution Control Federation meeting in Las Vegas in October. We expect that our POTW study will be completed and the results will be presented along with the results of some research work that is to be conducted on organics and heavy metals.

Looking into the future and ensuring my invitation to our next EPA/AES conference, I will now explain our current BAT efforts on the Mechanical Products Industry. Electroplating is often found to be part of this industry. The industry covers about 40,000 facilities ranging from automobile and aircraft manufacturing to very small manufacturers of mechanical and electromechanical products. We are finding that the greatest volume of discharge comes from the electroplating operation at these plants. We still haven't decided exactly how to go about subcategorizing this very complex industry. Also, we will have to decide how to handle what we call combined treatment, that is the mixing of electroplating wastewater with wastewater from other sources prior to treatment. This "comingling" of wastewater, treating each process source separately, has in most situations a sound engineering basis. But comingling also causes great consternation amongst people in the Agency for very good reason. Since most of the technologies that we are talking about are concentration limited, mixing wastewaters that contain heavy metals can lead to a scenario where many more toxic materials can be discharged. Since the treatment technology is concentration limited, independent of the influent concentration, the increased discharge results in an increase in total pounds that are released to the environment. This issue is still under active discussion within the Agency.

The daily maximum numbers that are in the regulation at present are:

Copper	4.5	mg/l
Chrome	7	mg/l
Nickel	4.1	mg/l
Zinc	4.2	mg/l

Our study is showing - and this *DOES* include combined treatment systems - that we are able to achieve lower metal concentrations with better technologies that we are evaluating. Such technologies include chemically-assisted clarification. We are finding that copper can be reduced from 4.5 to 2.5 mg/l, chrome from 7 to 2.5 mg/l, nickel from 4.1 to 0.7 mg/l, and zinc from 4.2 to 1.4 mg/l. These are the kinds of differences we are seeing in our preliminary evaluation of our data base. When we have our technical report together, as an informal rule making process that we go through, we will circulate the information to you for your review. This step is not a formal ruling; it will be your opportunity to comment on the technical aspects and technical merits of our data base. One thing that is important, though, is that we do not have a great deal of information. We are looking at many other industries that have similar types of problems and are pooling the data. For example, the inorganic chemicals industry has many heavy metal problems that are similar; we also have applicable treatment technology data from that industry.

Also of interest to you, is a "treatability" manual currently being developed under a joint effort between my office and EPA's Office of Research and Development under the direction of Bill Cawley, who spoke to you earlier. Our data on organic and inorganic pollutants is being utilized to describe how various technologies will perform when properly operated. This manual will be used in the field by regional and state officials to assist in making determinations where guidelines may not directly apply to a given problem or to a given industrial facility. The manual should be available by mid-year. It will not be published as a formal regulation; it will be made available for comment and I urge you to take a look at it.

I have mentioned organics briefly. In our BAT study, we have found significant amounts of some toxic organic pollutants being discharged. We feel that the source of these organics is the dumping of solvents. These solvents should be placed in a drum for disposal or, when we reach a point when it is economical, let's go with resource recovery. We are going to try to discourage solvent dumping.

Finally, Steve Schatzow mentioned our interest in incentives, in innovative technologies with the goal of approaching zero discharge. I heard this morning that the goal is not impossible. I head this morning that your association is looking in that direction. We are not in a position nor do we want to be in a position of saying that we must reach zero discharge by 1985. But we are extremely interested in these kinds of pursuits and we fully encourage them. It is also encouraging to me that we have the opportunity or the options down the road of having economical ways to approach the goal of the Act.

I hope that when I see you again next year, you have all your treatment in, all your pretreatment programs operable, and that you will be looking forward to the solid waste regulations.

POTW Removal Credits and Revised Categorical Pretreatment Standards

Jon L. Olson and Richard W. Eick*

INTRODUCTION

The Sanitary District of Rockford wastewater treatment plant provides a secondary-type treatment for an estimated connected population of approximately 200,000 people and wastewaters from some 500 industries belonging to the U.S. Environmental Protection Agency's 21 subcategories.[1] Based upon District information, it has been determined that 38 industries can be defined as belonging to the Electroplating Subcategory and presently discharge approximately 8 MGD to the sanitary sewer (approximately 20-25% of treatment plant flow).

In the early 1960's the District final effluent, which received primary and trickling filter-type secondary treatment, contained a considerable amount of cyanide (see Figure 1). As a result, there were a few fish kills in the receiving stream, which required action by the Sanitary District and, consequently, by Rockford Industry. In 1966, the District approved a 2.0 mg/L cyanide limit on all industrial discharge to the sanitary sewer. The addition of a secondary wastewater treatment system by the District in 1969 improved the amount of cyanide removed in the treatment process, resulting in lower effluent cyanide concentration. In 1974, Ordinance 309 went into effect and lowered the cyanide limit to 1.2 mg/L and included for the first time heavy metal limitations on industrial discharges.

Ordinance 309 industrial discharge limitations for cyanide and heavy metals were calculated by the District's staff who took into consideration, for the first time, the amount of pollutant removed by the wastewater treatment plant. The District derived the following pollutant discharge formula, which was incorporated into Ordinance 309:

Pollutant Discharge Formula

$$\frac{\text{Effluent Standard}}{100\text{-}(\%)\ \text{Removal}} \times \frac{\text{SDR Flow}}{\text{Pollutant Flow}} = \frac{\text{mg/L Pollutant Discharge}}{\text{Limit}}$$

Where:

EFFLUENT STANDARD is the applicable Federal, State or Local Effluent standard for any specific pollutant, in mg/L.

% REMOVAL is the average percent removal of the specific pollutant effected by passage through the treatment works during the preceding twelve months based upon daily analysis.

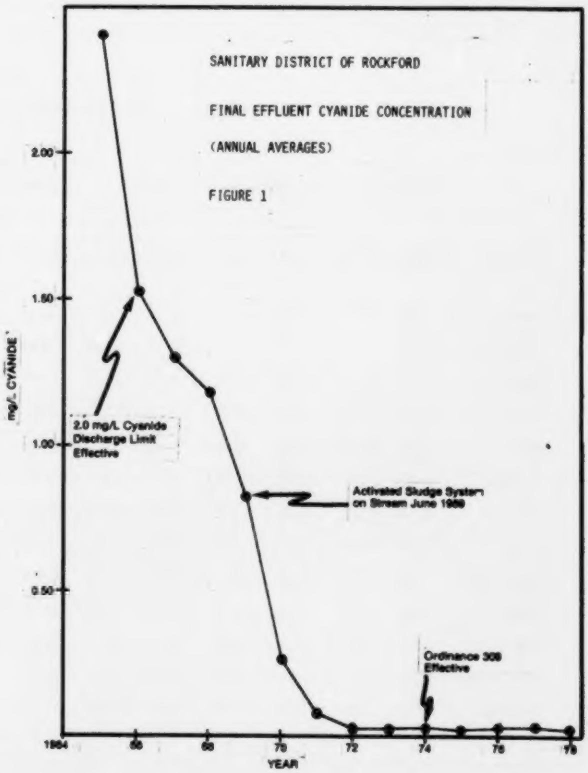
SDR FLOW is the average flow received at the treatment works during the preceding twelve months, in millions of gallons per day.

POLLUTANT FLOW is the total of flows from all known sources which contain or may contain the pollutant for which the calculation is being made, in millions of gallons per day.

POLLUTANT DISCHARGE LIMIT is the maximum allowable concentration of the specific pollutant which may be discharged to a public sewer, in mg/L.

The industrial pollutant discharge limits, as calculated by the above formula and incorporated into Ordinance

Figure 1—Final Effluent Cyanide Concentration (annual averages).



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[1] General Pretreatment Regulations for Existing & New Sources of Pollution. Federal Register June 26, 1978, Part IV. Appendix C.

Table I
Ordinance 309/341 Pretreatment Standards

Pollutant	*Pollutant Discharge Limit mg/L* *Ordinance 309*	 *Ordinance 341*
Cyanide (by distillation)	1.2	0.9
Copper	17.6	17.6
Cadmium	2.0	2.0
Nickel	6.7	6.7
Chromium (Total)	21.8	21.8
Chromium (Hexavalent)	3.6	3.6
Zinc	16.5	16.5
Iron	56.0	56.0
Lead	1.5	1.5

Ordiance 309 passed in 1974
Ordiance 341 passed in 1976

309 (present Ordinance 341), is given in Table I. These limitations have been and are presently being applied to industries regardless of their subcategory.

The 1979 annual average cyanide and heavy metals concentrations in the final effluent are given in Table II along with their respective treatment plant removal efficiency. This data has been collected since 1973 and collection will continue in the future, with some changes to reflect the Proposed Amended General Pretreatment POTW sampling requirements.[2]

The USEPA's removal credit formula to revise categorical standards was given in the General Pretreatment Regulations of June 28, 1978 Federal Register as follows:

$$\frac{\text{Revised Categorical}}{\text{Standard}} = \frac{\text{Categorical Standard}}{1 - r}$$

Where "r" is the percent of the pollutant (expressed as a fraction) that is removed by the POTW.

Although the basic concept of applying the POTW removal credits to an industrial discharge limit is common to both the District and the USEPA methods, the overall formula and application differs considerably. The major difference, as outlined in Table III, will result in stricter limits under the USEPA method. This is, of course, only conjecture at this time and assumes the approval of the removal credit concept by the USEPA method. In order for the Sanitary District to receive conditional revisions of categorical pretreatment standards, if at all, there is a considerable amount of work to be completed by Industry, the USEPA, and the POTW. Once all the data and reports are completed, an appropriate decision can be made by the USEPA as to the applicability of removal credits.

Procedure for Revising Categorical Pretreatment Standards to Reflect POTW Removal

The October 29, 1979 proposed amendments[3] to the General Pretreatment Regulations outline seven provisions to be included in a POTW application for revised categorical pretreatment standards.

(Section 403.7 (b)(2)(v)(i-vii). The Sanitary District of Rockford has indicated to the USEPA, Region V , in a letter and general method outline dated December 18, 1979, of its intention to so apply. It is important to the Sanitary District's pretreatment program and to

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[2] Federal Register Volume 44, No. 210. October 29, 1979, Section 403.7(c)(2)(iii) and (iv).

[3] Federal Register Volume 44, No. 210. October 29, 1979.

Table II
Final Effluent Quality and Percent Removal for 1979

	Copper		*Cadmium*		*Nickel*		*Total Chromium*		*6+ Chromium*		*Zinc*		*Iron*		*Cyanide*	
Month	*mg/L*	*% Rem.*	*mg/L*	*% Rem.*	*mg/L*	*% Rem.*	*mg/L*	*% Rem.*	*mg/L*	*% Rem.*	*mg/L*	*% Rem.*	*mg/L*	*% Rem.*	*mg/L*	*% Rem.*
January	0.27	80.0	0.07	63.2	0.21	34.4	0.10	85.1	0.05	90.9	0.70	76.2	0.68	93.3	0.029	90.3
February	0.25	79.2	0.07	69.6	0.18	28.0	0.08	88.7	0.04	77.8	0.61	80.1	0.22	95.0	0.021	93.6
March	0.42	53.8	0.08	57.9	0.18	28.0	0.08	79.5	0.04	63.6	0.85	61.5	0.38	89.0	0.026	91.0
April	0.33	54.8	0.07	58.8	0.15	16.7	0.07	75.0	0.03	70.0	0.66	55.1	0.36	87.0	0.033	84.3
May	0.30	66.3	0.07	58.0	0.14	33.3	0.04	89.5	0.02	80.0	0.56	72.8	0.21	94.2	0.040	86.7
June	0.13	83.8	0.03	88.9f	0.12	33.3	0.02	95.0	0.02	93.9	0.29	88.1	0.18	95.6	0.031	87.6
July	0.14	84.9	0.02	92.0	0.12	42.9	0.022	94.2	0.002	93.3	0.29	88.1	0.18	95.6	0.031	87.6
August	0.14	84.9	0.02	91.3	0.09	47.1	0.021	95.5	0.001	90.0	0.33	86.0	0.24	97.9	0.051	83.0
September	0.08	90.0	0.01	94.7	0.11	56.0	0.02	95.0	0.00	100.0	0.21	87.8	0.14	95.7	0.062	73.0
October	0.09	89.4	0.02	91.7	0.14	56.3	0.04	92.2	0.00	98.3	0.26	86.0	0.20	93.4	0.055	80.4
November	0.12	87.9	0.02	90.0	0.16	50.0	0.04	91.3	0.00	98.0	0.34	81.7	0.33	92.4	0.061	80.9
December	0.24	71.1	0.05	73.7	0.20	52.4	0.05	86.1	0.01	85.7	0.45	75.9	0.32	90.5	0.061	74.6
Average	0.21	77.6	0.04	77.5	0.15	33.9	0.05	88.9	0.02	86.8	0.47	77.6	0.29	93.3	0.042	84.2

Table III
Comparison of USEPA and SDR Pretreatment Standards Determination and Application

Item	*SDR Method*	*USEPA Method*
1. Basis of Pollutant Limit	Treatment Plant NPDES Limitations	National Technology Based Standards
2. Removal Efficiency, "r"	Annual Average	Average of Lowest 50% of Values
3. Number Days "r" Determined	365 Days	48 Days (12 Days per Season)
4. Pollutant Concentration Consistency	Same Limit for All Industrial Categories	Pretreatment Limits Vary with Each Category
5. Industrial Sampling Point	Limit Applied End of Pipe from Entire Plant	Limit Applied After Pretreatment for That Category
6. Industrial Flow Diluted at POTW	Accounted for in the Pollutant Discharge Formula	Dilution by POTW not considered in Formula
7. Contaminated POTW Sludge	Not Considered, Applying Sludge to Landfill	To be Considered, Must Meet 405 Sludge Regulations
8. Limitation for 24-hour Composite	Limit as Calculated by Formula	Limit as Calculated by Formula
9. Limitation for Grab Sample	5 Times the 24-hour Limit	Same as Composite Sample

Rockford Industry to determine, as quickly as possible, which pretreatment standards will apply: revised or existing categorical standards. It is also hoped that an early application will help to clarify some of the existing problems and unknowns. The following seven provisions, A thru G, will be part of the Districts's application for revised categorical standards.

A.Industrial Reporting Requirements

These reporting requirements apply in the case of Rockford industry to the Electroplating Subcategory since they are presently the only group in Rockford with applicable final pretreatment standards. If these reports are not submitted by April 6, 1980, the applicable electroplating industry will not be eligible for the revised pretreatment standards, should they be granted by the USEPA. The seven elements of electroplating reporting requirements are given below:

1. The name and address of the Industrial User.
2. The location of such Industrial User.

This is the address of the Industrial Plant that is discharging the electroplating wastewater (if different from plant headquarters).

3. The nature, average rate of production, and standard industrial classification of the operation(s).

It is assumed that the SIC code and average rate of production would be useful should the District choose to utilize mass limitation based upon volume of product.

4. The average and maximum flow of the discharge(s).

The District also requires that the industry submit not only the total flow of each discharge, but also the volume of categorical process water, which in the case of the electroplating industries would be rinse wastewaters resulting from operations of alkaline cleaning, acid pickling, stripping, coloring, and waste which comes about from spills, batch dumps, and scrubber blowdown.

It is the District's understanding, at this time, that tumbling operations prior to plating (i.e. deburring) will not be included in the term electroplating process wastewater. The wastewater from this operation will be considered under the group 18, "Machinery and Mechanical Products Manufacturing."[4]

5. The nature and concentration of pollutants in the discharge from each regulated process.

This should include not only the concentration at the end of the pipe, but also the concentration of the electroplating process wastewater (or after pretreatment of such wastewater, if available).

6. A statement indicating whether Pretreatment Standards are being met and, if not, whether additional operation and maintenance (O and M) and/or additional pretreatment is required.

As written, the electroplating industry must respond as to whether they are meeting the electroplating pretreatment standards. However, if the Sanitary District has received approval from the USEPA to use the revised standard, then the Industries would respond to these. Also, these comparisons must be made not at the end of the pipe, but at the point where all the electroplating process wastewaters are combined.

7. If additional pretreatment and/or O and M will be required, the shortest schedule by which the Industrial User will provide such additional pretreatment.

To answer items 6 and 7 it is important that the electroplater know as soon as possible which pretreatment standards will have to be complied with: the existing electroplating pretreatment standards or the revised standards.

B.The Sanitary District must comply and submit data in accordance with the requirements of 403.7 (c)(1)-(7).

1. The District must supply a list of pollutants for which the revised pretreatment standards are requested.
2. Treatment plant influent and final effluent concentrations for the above pollutants must be presented on a daily basis using 1979 data. These influent and final effluent samples were taken on a 24-hour basis at a frequency of 6 grabs per hours using a refrigerated FMC composite sampler. However, this past data, although comprehensive, is not entirely compatible with those of the proposed General Pretreatment amendments because of sampling techniques employed.
   a. The influent and final effluent composite samples were not taken proportional to flow. This was changed this year under completion of an addition to the plant activated sludge system, and also a new influent

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[4] Federal Register June 26, 1978, Volume 43, No. 123 "*General Pretreatment Regulations* . . .." Appendix.

[5] Federal Register June 26, 1978, Volume 43, No. 123 "*General Pretreatment Regulations* . . .." Section 403.7 (c)(1-7).

sampling room which was part of the new administration building expansion. Henceforth, the samples will be taken proportional to flow.

b. The final effluent composite samples must incorporate the concept of detention time into the sampling sequence. This has not been done in the past, i.e. both the influent and final effluent composite samples were pulled daily at 12:00 midnight. This was changed on January 1, 1980 when the influent composite sample was changed at 12:00 midnight, while the final effluent was pulled at 10:00 a.m., i.e. a 10 hour average POTW retention time was used. Henceforth, the influent and final effluent composite samples will be taken as described above.

c. The cyanide analyses were made daily on the usual 24-hour composite samples rather than on the grab samples as required by 403.7 (c)(2)(iv). The grab sample techniques can be utilized in the future for comparision with the present method of determining the removal efficiency.

The Sanitary District believes that the data on the above influent-final effluent samples collected as described above, will give an accurate and demonstrable indication of the pollutant removal efficiency, especially since 365 individual days' removal efficiencies will be examined for each pollutant using an IBM 370 computer. The program will be written to compare consistent removal determined by . . . "the average of the lowest 50 percent of removal measured. . . ."[6]

It is the District's belief that, because of the prodigious amount of influent-effluent data, the 1979 data used will adequately demonstrate the removal efficiencies.

3. The Sanitary District will supply a list of all the industries that are presently known to be members of the Electroplating Point Source Category and which of the pollutants each discharges.

4. The proposed revised Electroplating Pretreatment Standards that will apply to the above industries will be submitted. The formula, as given in 403.7 (c)(4)(i) shall be used to calculate the revised pretreatment standards.

$$\frac{\text{Revised Categorical Standard}}{} = \frac{\text{Categorical Standard}}{1 - r}$$

Where "r" is the percent of the pollutant (expressed as a fraction) that is removed by the POTW.

5. A table listing the concentrations of the approximate pollutants as found in the sludge thickening tank underflow sludge for 1979 will be submitted. This underflow sludge, which is composed of 50% primary and 50% waste-activated sludge, is sampled on a composite basis every two weeks and the appropriate analysis made.

The above sludge is pumped to the vacuum filter building for conditioning with lime and ferric chloride, followed by dewatering with Komline Vacuum Filters. The resulting cake is disposed of in an Illinois EPA approved landfill. This vacuum filter cake is also sampled and analyzed every two weeks for these same pollutants.

6. A description of the POTW's current sludge disposal methods will be supplied to the USEPA. Any current sludge disposal permits with the IEPA will be included with the description.

7. The District will certify that, except where noted, the pollutant removals and the revised standards were determined as outlined in the USEPA regulations.

C. Industrial Compliance Schedule with the POTW

Electroplating type industries who are not able to meet the electroplating categorical pretreatment standards (or revised pretreatment standards, if known and approved by the USEPA) must enter into a compliance schedule with the Sanitary District of Rockford. This compliance schedule should culminate with pretreatment systems that will insure compliance by October 7, 1982. In this regard, it is imperative that the electroplating industries know whether revised pretreatment standards will be allowed. Industrial failure to submit a compliance schedule or to meet any of its scheduled events will mean the industry will not be eligible for revised pretreatment standards.

Another similar issue is whether the BAT pretreatment standards, yet to be promulgated, will have stricter standards for the typical electroplating pollutants. Industry needs to know and so does the POTW.

D. The Sanitary District Must Apply for the Pretreatment Program Approved in a Timely Manner

This will be done and, in fact, the majority of the data regarding Rockford Industries and toxic pollutants, especially cyanide and heavy metals, has already been collected. The Sanitary District is waiting for a State Grant approval so that an inspector can be hired to concentrate on organic priority pollutants and Rockford Industry. It is expected that this yet to-be-hired individual will make inspections of all Rockford industry with a knowledgeable industrial representative from each industry.

This information along with the effluent, and sludge organic priority pollutant analysis (which was already completed separately by the USEPA and the University of Washington, Seattle) should give us a good picture in this area.

The Sanitary District must enter into a compliance schedule for development of the pretreatment program which will be made part of a revised Illinois EPA NPDES Permit. This compliance schedule will serve as a guide post to gauge the District's progress toward pretreatment program approval.

E. Termination of Conditional Removal Credits

The conditional revised standard will be terminated by the control authority if the District does not comply with the following:

1. Unable to maintain removal efficiencies
2. SDR does not apply for the pretreatment program in a timely manner.
3. The District does not comply with the sludge use as defined in Section 405 guidelines or any other guidelines.

Should the District fail to comply with 1, 2, or 3 above, the industries must achieve compliance with the applicable pretreatment standards before the prescribed time period for those standards.

F. Company Failure to Comply

If a company fails to comply with its reporting requirements, or fails to submit or meet the compliance dates, then the conditional standards for that particular company are terminated. That company must meet the applicable pretreatment standards in the required time period.

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[6] Federal Register October 29, 1979; Volume 44, No. 210, Section 403.7 (a)(1).

G. The Sanitary District must submit the name and address of each Industrial User that has been given conditionally revised discharge limits each December 31st. Upon revocation, the District must submit, to the control authority, the industrial information as given in II, A, 1-7. The Industry limits will than revert to the categorical pretreatment standards.

CONCLUSION AND DISCUSSION

Under the new pretreatment regulations, the Rockford industries belonging to Electroplating Subcategory will be required to meet stricter discharge limits than presently imposed by District Ordinance. To what extent will depend upon whether POTW removal credits will be allowed. It is imperative for Industry and the POTW that an early decision on this concept be made by the USEPA.

The issue of contaminated POTW sludge resulting from cyanide and heavy metal removal is one of the primary factors influencing this concept. It is hoped that the 405 sludge regulations will define the sludge disposal options that are available to the POTW. It would appear, from many previous comments by the USEPA, that only agricultural application of municipal sludge will be considered. What is to happen with the municipalities that are presently using approved incineration or landfill disposal techniques? The decisions made by the USEPA on the desired sludge "quality", once made, must be applied uniformly and equally throughout the United States.

Another problem that the USEPA must resolve is the application of different pretreatment concentration limits of a similar pollutant from different subcategories to a single industrial discharge. If this single company has a common pretreatment system, which pretreatment standards are applicable?

The POTW will be responsible for submitting its Pretreatment Program to the control authority for approval in a timely manner. The Sanitary District of Rockford is committed to this and expects to receive approval by the July 1983 deadline. If past experience is any guide, there are many as yet unknown problems ahead for the District in the fair, reasonable, and just application of these regulations to Industry.

The Industries, as required, will have to install appropriate pretreatment systems to meet the discharge limitations to the sanitary sewer. Industry should, at this point, consider two very important factors that will determine the ultimate success of their pretreatment system: (1) if necessary, have an *experienced* consultant help with the design engineering. Checking with his past clients could be informative. (2) Have a qualified pretreatment system operator to run the operation and make him responsible for the effluent quality. This operator must regard the effluent quality as his final product. After all is said and done, it is the effluent quality that is of primary concern and the reason for the Pretreatment Program.

Electrochemical Reactor and Associated In-Plant Changes at Varland Metal Service, Inc.

Edwin Roof*

INTRODUCTION

This report will describe the background and present status of the Joint Demonstration Project sponsored by the Metal Finishers Foundation and the Environmental Protection Agency at Varland Metal Service, Incorporated, Cincinnati, Ohio.

The purpose of this demonstration project is: to evaluate the use of a unique electrochemical system designed to reduce pollutants from an electroplating plant to meet EPA regulations; to evaluate the capability of the system to recover the valuable metals in the rinse water for re-use in the plating processes; and to minimize the formation of sludge.

Varland Metal Service, Inc. - Background

Varland Metal Service, Inc., is an electroplating job shop. The Company was founded in 1946 and incorporated in 1947 by Curtis M. Varland, W. Wilson Loveless, and Edwin Roof.

The Varland plant is a multi-process plant with the following processes: (1) automatic barrel cyanide zinc; (2) hoist barrel zinc, cyanide and chloride, (3) hoist barrel cyanide copper, bright nickel, tin, cyanide cadmium, cyanide brass; (4) automatic barrel cyanide copper and bright nickel; (5) hoist phosphating, barrel and rack; (6) hoist rack zinc and cadmium, cyanide; (7) automatic rack cyanide zinc; (8) rotary barrel chromium; (9) basket and rack chromium; (10) mechanical plating, zinc, cadmium, and tin; (11) chromating, bright dipping of brass, passivating of stainless steel and other similar processes.

The Varland plant has approximately 47,000 total square feet of floor space. Annual sales are in the $2,500,000 to $3,000,000 range; total employment numbers 60 to 70.

In 1974, a major step towards furture compliance with local and federal anti-pollution regulations was the establishment of a modern laboratory for analysis of waste streams. Included was an atomic absorption spectrophotometer for analysis of metal discharges. Later in 1974, an engineer was employed to set-up a comprehensive sampling and analytical program to determine what steps should be taken to meet regulations.

By the end of 1976, it was clear that much work needed to be done. City of Cincinnati revised regulations of Sept. 1, 1976 with a compliance deadline of July 1, 1979, called for the following limits:

CN-T	10 mg/L	Cr-T	6 mg/L
CN-A	2 mg/L	Cd	3 mg/L
Zn	6 mg/L	pH	6.0 to 10.0

Final EPA pretreatment limits had not yet been promulgated, but they were expected to be even tighter. By contrast a typical analysis of the wastewater at that time was

PPM IN 24 HR COMPOSITE SAMPLE

Usage, gal	*pH*	*CN-T*	*Cd*	*Cr*	*Cu*	*Ni*	*Zn*
216,000	7.0	15.8	1.0	11.8	3.3	6.7	37.5

It was obvious that some type of waste treatment should be installed. Accordingly, an intensive real estate acquisition program was pursued to buy some additional land adjacent to the plant and a successful campaign was waged at City Hall, in spite of some neighborhood resistance, to get the newly acquired land rezoned so that waste treatment facilities could be installed.

By the end of 1977, an engineering firm was retained, and preliminary work was begun on design of a conventional treatment plant to treat 300,000 gallons of waste per day, to allow for growth. We felt we already had good water conservation with Dole flow restrictor valves on all rinses, and with all rinses being counterflow. At this point in time, we received the opportunity to participate in the MFF-HSA research project.

HSA REACTORS LIMITED - BACKGROUND

HSA Reactors Limited of Toronto, Canada is a company formed to research, manufacture and market these electrochemical systems. The system is based upon research undertaken in 1974 by Drs. Das Gupta and Fleet in the Department of Chemistry at Imperial College, University of London, England. The system features the use of an electrochemical cell with graphite electrodes designed to increase the mass transfer rates and thus increase the efficiency of the metal removal process. Early in 1975 this work was brought to the attention of Ian Kennedy, now the President of HSA Reactors Limited, by Dr. A. Barringer, of Barringer Research, Toronto, an alumnus of and visiting professor at Imperial College. During the latter part of May, with the help of numerous scientific and engineering consultants, an extensive test program was designed for the electrochemical system. This test program was conducted

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Cincinnati, Ohio

at Imperial College under the supervision of Mr. Kennedy in early June, 1975, with completely satisfactory results. An agreement to finance the ongoing research, development and commercialization of the system was rapidly concluded, and the company was incorporated on July 19, 1975.

The cell was orginally envisioned as having three possible practical industrial applications, namely pollution control of metals in solution, hydrometallurgy, and organic synthesis. At an early date, HSA decided to focus its efforts on pollution control applications.

BACKGROUND OF THE JOINT DEMONSTRATION PROJECT

In June, 1976, at the AES Convention in Denver, Ian Kennedy met Simon Gary, of Scientific Control Laboratories, Chicago, and they discussed the invention. Mr. Gary recommended that HSA contact NAMF's Metal Finishers Foundation, and this was done. As a result of this contact, Bill Crawford of Chrome-Rite Company of Chicago and Ed Durkin of Advance Plating Company, Cleveland, went to Toronto to investigate the use of these cells in the metal finishing environment. They were both impressed with the possibilities for the use of this cell in pollution abatement in the metal finishing industry and invited Mr. Kennedy to appear in December of 1976 at a meeting of the trustees of the Metal Finishers Foundation in Atlanta. Based on a presentation by Mr. Kennedy and confirmed by the observations of Mr. Crawford and Mr. Durkin, the trustees of the MFF appropriated $15,000 towards the cost of a demonstration project in the Chrome-Rite plant in Chicago.

In June, 1977, at the Chrome-Rite plant, industrial scale research reactors were demonstrated by HSA personnel. All analytical work evaluating results was done by Scientific Control Laboratories. At the same time, a full scale plant assessment was done by HSA personnel, locating and classifying the point sources of pollutants in the Chrome-Rite plant.

The results of the demonstrations were phenomenal. This was later documented by Mr. Kennedy in a paper presented to the first EPA/AES Pollution Control Conference in Lake Buena Vista, Florida, in January 1978. The demonstrations confirmed the feasibility of an electrochemical treatment approach. The system was applied to end of pipe discharges both before and after a conventional alkali chlorination system as well as on individual rinse tanks discharges.

In October, 1977, following extensive discussions with Mr. George Thompson of EPA, HSA Reactors submitted to the Metal Finishers Foundation a proposal to participate in a joint demonstration program to demonstrate the technical and economic capabilities of their electrochemical reactor in waste treatment. MFF accepted the proposal and applied to EPA for a grant of $155,000. to finance a portion of the demonstration program. The grant was approved by EPA in June, 1978 and Varland Metal Service Incorporated, in Cincinnati was designated as the metal finishing plant for the demonstration program.

The Varland plant was one of five plants selected by MFF. Mr. Kennedy inspected the five plants and with the approval of EPA and MFF selected the Varland Plant.

The joint demonstration program was to be implemented in three phases. The initial part of Phase I involved a Plant Assessment Survey of the Varland operations, as shown in Figure 1.

The remainder of Phase I was to include a follow-up to the recommendations of the survey report and the design, construction, and installation of a series of reactor units.

Phase II of the program was to be composed of a six-month operation period for the reactor systems.

Phase III was to allow for a four-month analysis and evaluation of the operating data prior to submission of the final project report.

PLANT ASSESSMENT

1. Analysis of plant layout and operating practices
2. Examination of process water usage
3. Identification of sources of pollution
4. Recommendations for step-by-step program of changes
5. Basis of plan for controlling pollution

Figure 1

STRATEGY FOR POLLUTION CONTROL

The Joint Demonstration Program involves a rational approach to pollution control and to achieving compliance with effluent regulations. Rather than planning "end of pipe" treatment for existing plant operations, the strategy which Varland is following involves:

1. A thorough Plant Assessment (see Figure 1).
2. Implementation of point source recovery and treatment wherever possible.
3. Installation of final treatment equipment as necessary.

The first two steps in this strategy will reduce both the volume of process water and the pollution loading in this water which must be treated at "end of pipe." This is expected to result in lower cost for pollution control as well as significantly reducing the generation of sludge.

PLANT ASSESSMENT

In August, 1978, the Phase I Plant Assessment Survey was carried out by HSA at Varland, and a report of this Assessment was submitted to Varland and the EPA in October, 1978. The Plant Assessment included: (a) analysis of plant physical layout, operating practices and procedures and the recommendations of any changes which would result in lowering the contaminant levels in the final plant effluent discharge; (b) examination of process water usage and recommendation of ways to reduce the plant usage of process water as well as identification and segregation of the process waters not requiring final treatment; (c) sampling to determine the type, quantity and nature of the pollutants; isolation and identification of the point sources within the plant of these pollutants; (d) formulation of a step by step program to effect in-plant control of pollution, and; (e) providing a plan for compliance with local and EPA pre-treatment guidelines.

The Assessment resulted in more than forty recommendations for improving general operating

PLANT ASSESSMENT RECOMMENDATIONS

- Elimination of pollution sources
- Reductions in process water usage
- Housekeeping and maintenance
- Attitude toward pollution control

Figure 2

practices. (See Figure 2)

Most of the Recommendations made by HSA have been implemented or are planned to be implemented in our program to control pollution. In addition, we have applied the concepts discussed with HSA along with ideas from our own staff in continuing to look for other ways to reduce pollution levels.

Many of the changes which have been made are difficult to evaluate in terms of cost and more difficult to relate to specific benefits. For example, longer drainage times on some lines have slowed down production rates. However, we feel that the longer drainage times have contributed to reduced dragout and hence have facilitated the reduced usage of process water and saving of process chemicals.

Some specific results from the Plant Assessment can be identified as follows:

1. Process water usage has been reduced approximately 45% for a çost saving of $15,000 per year. More importantly, the basic principles will make possible further water savings in the future.
2. An annual saving of approximately another $11,000 has been achieved through a decrease in chemical usage.

VARLAND METAL SERVICE FINAL EFFLUENT ANALYSIS

	BEFORE PLANT ASSESSMENT (GRAMS)	AFTER PLANT ASSESSMENT (GRAMS)	DIFFERENCE (GRAMS)	(PERCENT)
Total Cyanide	11,973	10,513	—1,460	—12
Free Cyanide	9,191	5,356	—3,735	—41
Cadmium	885	743	—142	—16
Chrome	9,925	5,751	—4,174	—42
Copper	2,195	1,780	—415	—19
Nickel	5,812	4,054	—1,758	—30
Zinc	27,451	22,064	—5,287	—20
Daily Process Water Usage (Gallons)	205,000	113,000	—92,000	—45

Figure 3

3. The above reductions in process water usage and chemical usage will make a very significant contribution to reducing the pollution loadings in the final effluent and the costs for pollution abatement. (See Figure 3)
4. Another result of the implementation of the survey recommendations is a noticeable change in the attitude of our employees - a realization that success in meeting goals of the pollution abatement program is an absolute necessity in guaranteeing the future of their jobs.
5. The direct costs incurred to achieve the above savings consist of: (a) $5,000 capital cost of new conductivity cells and timer control valves (with an estimated 5 year life, for simplicity this can be considered as a $1,000 annual cost); (b) $7,500 annually for additional maintenance for the conductivity cells, additional cleaning of tanks, etc.

PLANT ASSESSMENT COSTS/BENEFITS

DIRECT TANGIBLE BENEFITS	PER YEAR
Reduced process water usage	15,000
Reduced chemical usage	11,060
	26,060
COST TO IMPLEMENT	
Conductivity cells	1,000
Labour (Maintenance)	7,500
	8,500
Net annual savings	17,560
PLUS:	
Reduced pollution control costs	

Figure 4

See Figure 4 for Cost/Benefit Ratio.

Some other costs required to meet Assessment Recommendations, but which are not directly connected with the cost savings are; (through Dec. 31, 1979).

1. Lining Tanks, Previously Unlined	$8,530
2. Titanium Anode Baskets to Replace Steel Baskets in Cyanide Plating Solutions (This does not complete the replacement program)	$5,833
3. New tanks, to set-up the "well ordered" lines, to replace some "disorganized lines"	$9,970
Total other costs	$24,333

Other highly significant information developed in the Plant Assessment is that the amount of production in a given process varies widely from week to week, and that, not surprisingly, the amount of the particular metal pollutant also varies widely from week to week, practically in direct proportion to the sales. This relationship was charted for barrel copper plating, barrel zinc plating, and barrel cadmium plating over a 5 week period. The sales variability (and pollution variability), defined as maximum weekly sales divided by minimum weekly sales, was approximately 3 to 1 for cadmium, 2 to 1 for zinc, and 6 to 1 for copper. This points out the fallacy of depending on any 1 day effluent monitoring to get a true picture of a particular plant's pollution problem; a longer study is necessary unless it is first established that the particular plant has very uniform production.

Also highly significant is the fact that regular "dumps" of process solutions contribute greatly to the pollution load. These are not "dumps" of plating solutions or concentrated process solutions or dips, discarded alkaline cleaner solutions, acid pickling solutions, etc. These solutions are normally bled into the discharge slowly so that the normal pH control keeps the effluent within acceptable limits. The contribution of such "dumps" for one typical week to the effluent was, in mg/l:

Zn	*Cu*	*Ni*	*Cd*	*Cr*
23	0.4	0.3	0.1	8.8

HSA has identified the above problem and is presumably working to develop a solution.

HSA REACTOR

The main thrust of the HSA Reactor program thus far has been the development of a closed loop reactor treatment system to work with cyanide plating solutions, cadmium, copper, and zinc, to destroy the cyanide and recover the metals from the rinses immediately after the plating bath.

A cadmium unit has been in operation in the plant for almost one year, but has been extensively modified or rebuilt from time to time, a normal procedure for research and development units. A unit similar in design principles to what will be offered in the near future as a commercial unit is presently in operation in the plant, and that unit will be described here.

SCHEMATIC OF HSA REACTOR SYSTEM

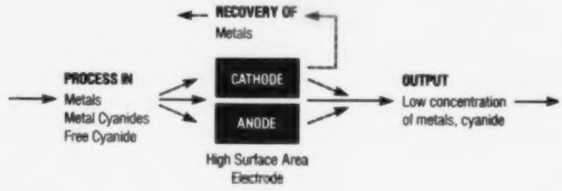

RECOVERY OF
Metals
PROCESS IN
Metals
Metal Cyanides
Free Cyanide
CATHODE
ANODE
High Surface Area
Electrode
OUTPUT
Low concentration
of metals, cyanide

Figure 5

Figure 5 is a schematic representation of the reactor system. During the plating step, the metal is deposited on the carbon fibre cathode while cyanide is electro-oxidized and electrochlorinated at the anode. After the cathode is sufficiently loaded, the metal is stripped into a separate solution. The metal is recovered either by electrowinning from the strip solution or by using a strip solution compatible with the plating bath and adding the metal concentrate directly to the bath. Figure 6 shows, schematically, the work flow through the cadmium plating bath and the Reactor Process Solution. Figure 7 shows the solution flow and Figure 8 shows the combined work flow and process solution flow in our plant.

CADMIUM PLATING SEQUENCE

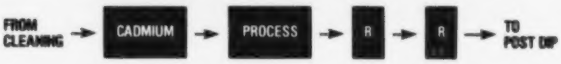

FROM
CLEANING
CADMIUM
PROCESS
R
R
TO
POST DIP

Figure 6

The solution from the dragout tank on the cadmium barrel line is pumped through the reactor to the dragout tank on the cadmium hoist line, then back to the cadmium barrel line to close the loop. In this way, one reactor handles the cadmium from two sources. Our production is normally higher in the barrel line and the dragout tank is smaller (160 gal vs 700 gal), thus this arrangement sends the highest concentration of metal into the reactor, allowing it to operate most efficiently.

HSA REACTOR PROCESS FLOW

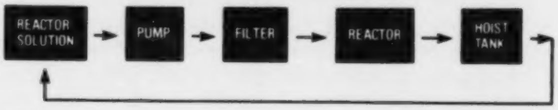

REACTOR
SOLUTION
PUMP
FILTER
REACTOR
HOIST
TANK

Figure 7

PROCESS FLOW DIAGRAM FOR CADMIUM REACTOR SYSTEM INSTALLATION AT VARLAND

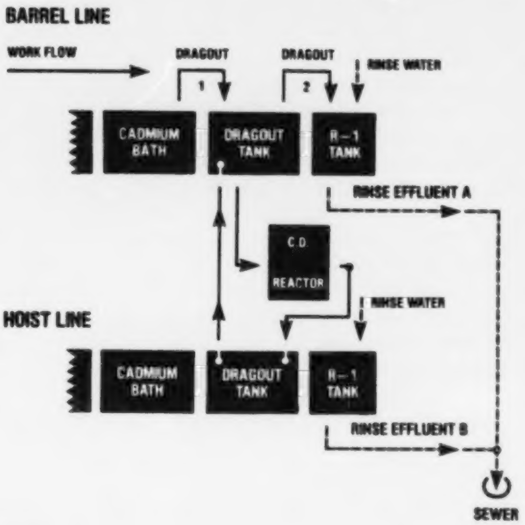
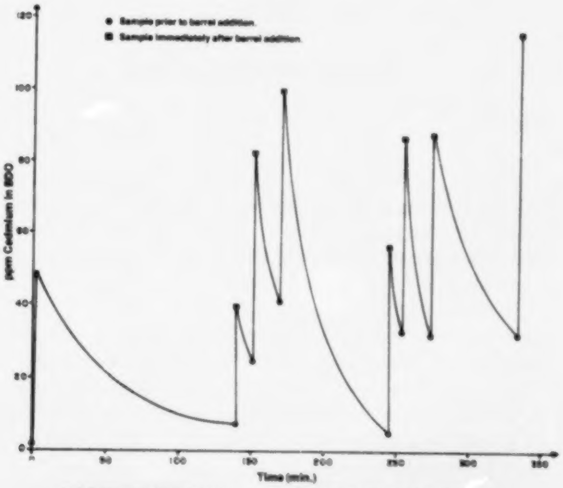

BARREL LINE
WORK FLOW
DRAGOUT
1
DRAGOUT
2
RINSE WATER
CADMIUM
BATH
DRAGOUT
TANK
R-1
TANK
RINSE EFFLUENT A
C.D.
REACTOR
RINSE WATER
HOIST LINE
CADMIUM
BATH
DRAGOUT
TANK
R-1
TANK
RINSE EFFLUENT B
SEWER

Figure 8

The comparatively large volume of hoist rinse solution acts as a buffer and prevents sudden surges in cyanide or cadmium concentrations.

The closed loop process solution is maintained at pH 10 with NaOH and sodium chloride is maintained at 100 g/l.

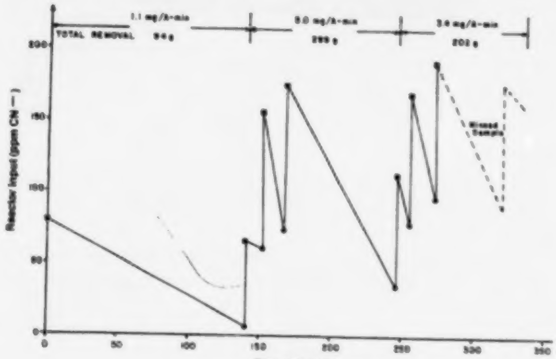


CADMIUM REMOVAL — BARREL DRAG-OUT TANK

Figure 9

Figure 9 shows the performance of the unit for cadmium removal. As each barrel is rinsed, approximately 1 1/2 liters of solution, 27 grams Cd and 100 grams CN, is dragged into the system. In the test shown here, the maximum cadmium dragged out from the HSA process rinse into the running rinse was about .18 grams of cadmium per barrel, thus effectively removing 99.4% or more of the cadmium that would otherwise have gone into the effluent. The reactor plated out enough cadmium so that a low concentration would be found in the process tank when the next barrel load was rinsed. The D. C. power to the reactor was 600 amps at 4 volts; flow rate was 40 liters per minute.

Removal rates for cadmium depend on the concentration of the solution entering the reactor. With a comparatively low production level during this test, cadmium was removed at an average rate of 0.6 mg per minute or, at 600 amps, 1 mg per ampere minute. Other tests, not shown in detail here, indicated cadmium removal rates of 8 mg per ampere minute with an input to the reactor of 200 to 250 mg/l from the process solution. In this test, cyanide was not completely removed. The flow rate at 40 liters per minute and the current, 600 amps at 4 volts, remained unchanged. This concentration in the drag out tank would correspond to 99% removal of the cadmium that would otherwise be discharged to the sewer. If this removal rate is considered in relation to an average total plant flow of 300 liters per minute, a production rate of 5 barrels per hour would still leave the cadmium in the effluent from this source at less than 0.1 ppm; without the reactor, the cadmium would be 10 ppm from this source.



REMOVAL RATE FOR CYANIDE

Figure 10

Figure 10 shows Removal Rate for Free Cyanide under the same conditions as shown in Figure 9 for cadmium removal; 600 amps at 4 volts, flow of 40 liters per minute. Removal rates shown here and confirmed by other work indicate a removal rate of about 4 mg per ampere minute with input to the reactor in the 200 to 600 mg/l range. A production rate of 1.4 barrels per hour would be at equilibrium with this removal rate. If this is compared to an average total flow of 300 liters per minute, free cyanide in the effluent from this source would be under .03 mg/l. Without the reactor, free cyanide would be almost 8 mg/l at 1.4 barrels per hour.

The reactor system used in the above tests had one reactor module containing six reactor frames. A system of this size under our operating conditions was able to treat the dragout from 1.4 barrels per hour. More frames can be added to the module and additional modules can be added to the system according to operating conditions and dragout levels to be treated.

The size system required also depends on whether or not cyanide removal is to be done entirely by the reactor system. As previously indicated, one could take advantage of significantly higher metal removal rates if some of the cyanide were to be destroyed with chlorine or sodium hypochlorite.

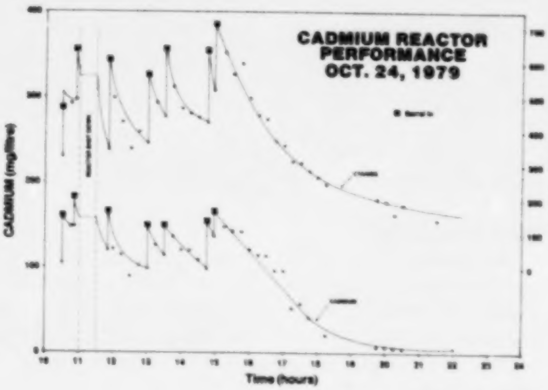


Figure 11

Figure 11 shows a different test of cadmium reactor performance - in this graph, the cadmium removal and the cyanide destruction are shown together. The removal rates are essentially the same as previously stated.

To summarize, if this reactor unit is operated with one 6 frame reactor module, 600 amps, 4 volts, and a production rate of 1.4 barrels per hour average, and total plant effluent is 300 liters per minute, total contribution to the effluent from this source will be under .015 mg/l cadmium, under .03 mg/l free CN. Without the reactor system in place, the comparable contributions would be 2.8 mg/l cadmium and 7.8 mg/l free CN. This constitutes better than 99 1/2% removal of both cyanide and cadmium. The same reactor unit could give approximately the same level of cadmium in the final effluent at a considerably higher production rate, but some portion of the cyanide would have to be destroyed with NaOCl. Also, satisfactory performance could be achieved at any production rate by increasing the size of the system.

Please note that the above capacity figures do not allow for lost reactor time for stripping, down time for maintenance, etc. However, on the other side of the coin, removal and destruction capacity can be increased somewhat, but not proportionately, by increasing the amperage from 600 to 800.

Please also note that all cyanide analyses are for "free" cyanide - no distillation step was used as is required in CN-T analysis for final effluent.

Much of the experimental work done to date deals with the method of stripping and recovering the cadmium from the cell. The initial method used a sulfuric acid solution; this worked quite well. The cadmium could be recovered from the solution by electrowinning.

By modifying the cell design, it is possible to use a different stripping scheme. This utilizes a heated cyanide solution, made up by using some of the plating solution from the bath and augmenting the cyanide content. The enriched solution will be returned at intervals to the bath and fresh plating solution will be made available for

CADMIUM LEVEL IN FINAL EFFLUENT

POINT SOURCE	CONTRIBUTION (ppm)	TREATABLE BY HSA REACTOR
Hoist/Barrel drag-out	1.2 — 2.0	✓
Cleaners/Strips	0.4 — 0.6	✓
Dips	0.3 — 0.5	

HSA predicts:

Cadmium in final effluent ↗ Without HSA Reactor → 1.9 — 3.1 (ppm)

Cadmium in final effluent ↘ With HSA Reactor → **0.4 — 0.6 (ppm)**

Figure 12

stripping. This method also seems to work well. None of the enriched solution has yet been added to the production bath, but Hull Cell tests indicate that such additions will cause no difficulty.

Figure 12 is an estimate by HSA of what our cadmium will be in the final effluent based on full time use of the existing reactor unit in the plant and based on total cadmium production being approximately where it has been for the last year. The 0.4 to 0.6 is, of course, well below EPA's standard of 1.2 for daily maximum and 0.7 for the 4 day average.

BARREL ZINC PLATING SEQUENCE

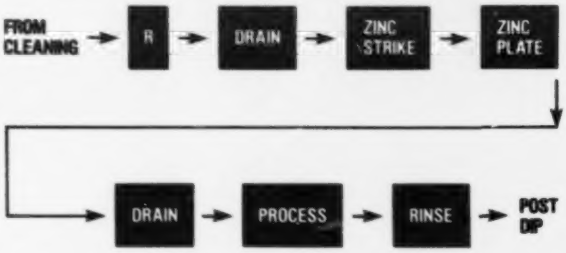


Figure 13

COPPER AND ZINC UNITS

The Reactor Unit for Copper (to be used on two cyanide barrel copper plating operations) was delivered on April 7, 1980, and was installed and operating by April 14, 1980. No test data on its use in our plant is yet available, but test results from HSA's lab indicate it should operate well. The unit has 4 reactor cells, connected in parallel for solution flow and in series electrically. Stripping of the copper from the cell will be done with a cyanide solution. The process flow diagram will be quite similar to that shown for zinc. The zinc unit is scheduled for delivery and installation April 30, 1980. Figure 13 shows the work flow through our barrel zinc automatic plating machine. Figure 14 shows the planned process solution flow from the various zinc sources to the reactor.

In both the copper and zinc systems, we will use a surge tank to supply process solution to the reactor. This tank has two compartments separated by an overflow dam - total volume is 550 gallons. The zinc reactor pumps from the dirty side, zinc wise and cyanide wise, through the reactor, returning the solution with decreased zinc and cyanide content to the clean side. At the same time, "clean" process solution is pumped to the dragout recovery tanks on the various zinc lines, three of which are shown here. The loop is closed by returning "dirty" process solution back to the "dirty" side of the surge tank.

PROCESS FLOW DIAGRAM FOR ZINC REACTOR SYSTEM INSTALLATION AT VARLAND

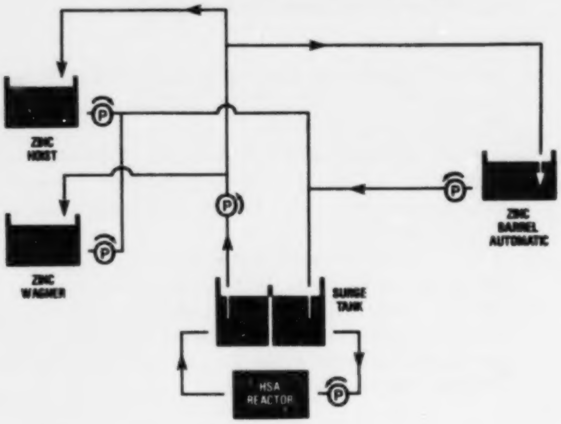


Figure 14

PROPOSED CLOSED-LOOP TREATMENT SYSTEM FOR ZINC PLATING LINE

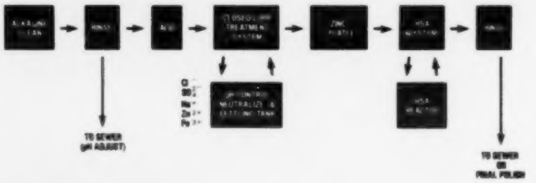


Figure 15

Figure 15 shows how we plan to complete the job on our zinc plating operations by using a closed loop treatment system for rinsing after acid pickling before plating. We plan to settle or filter out the iron in the rinse while allowing the zinc to remain in solution and be dragged into the plating bath.

Finally, Figure 16 shows a brief summary of the desirable features of the HSA Reactor System.

I want to take this opportunity to thank the personnel at HSA for their help with this paper and for their continued work in our plant to help us, and hopefully much of the plating industry with what appears to be a

FEATURES OF HSA REACTOR SYSTEM

- Electrochemical system
- Metal recovery without impurities
- Low operating costs
- No sludge produced
- Compact, modular units

Figure 16

very valuable tool in pollution control. I particularly want to thank Ian Kennedy, Sankar Das Gupta, Bernard Fleet, John Moore, and Graham Dickson.

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The Application of Separation Processes In The Metal Finishing Industry

Peter Crampton*

ABSTRACT

The high cost of raw materials and pollution control provides the economic incentive to invest in process units which reclaim raw materials from waste streams. Evaporation, ion exchange, reverse osmosis, and electrodialysis are separation processes which have found application for raw material recovery. The range of applications of these processes, as well as the economic factors which limit their use are explored. Low cost plating drag-out recovery systems and the economics of wastewater recycle processes are high-lighted. Also discussed is the application of metal selective ion exchange resins to "polish" the effluent from a conventional hydroxide treatment process.

INTRODUCTION

Today, both economic and regulatory pressures are having significant impact on the cost of doing business in the metal finishing industry. Raw materials and utility prices have increased markedly. Environmental controls on wastewater discharges and solid waste disposal impose an additional penalty for inefficient use of raw materials. The economic incentive for making more efficient use of energy, water, and raw materials is significantly greater for metal finishing firms than it was several years ago.

Processes which recycle raw materials from what were formerly waste streams have found increasing use. The justification for the recovery processes are derived from reduced operating costs for end-of-pipe pollution control and raw material savings. These processes have in common the ability to separate specific compounds from a water solution, yielding a concentrate of those compounds and relatively pure water. The processes which have enjoyed the broadest commercial success in this area include evaporation, ion exchange, reverse osmosis, and electrodialysis.

EVAPORATION

Figure 1 shows an evaporator used to concentrate rinse water and recycle drag-out back to the plating bath. Plating chemical recovery is the only commercially significant application of evaporation in the metal finishing industry. As shown, the condensed vapor overhead is of high purity and is reused for rinsing. This particular system utilizes closed loop recovery. The closed loop recovery system has the advantage of totally eliminating a water discharge from the plating process. Such an approach, however, requires sufficient water to be evaporated and recycled to satisfy rinsing requirements. With the high cost associated with energy, high evaporative rates can quickly erode the savings associated with raw material recovery.

Figure 2 depicts an evaporative recovery system reclaiming chemical dragout from a chromium plating operation. This recovery system is an open-loop type. The rinse rate in the recovery rinse section is set to achieve the maximum savings in terms of operating costs. The balance of the rinsing is be accomplished in the free rinse, which discharges to waste treatment.

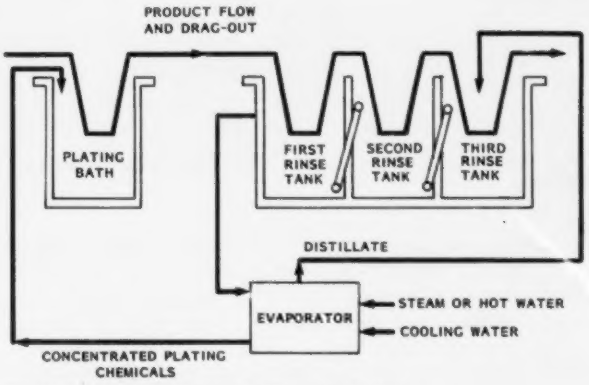

Fig. 1—Closed-Loop Evaporative Recovery System.

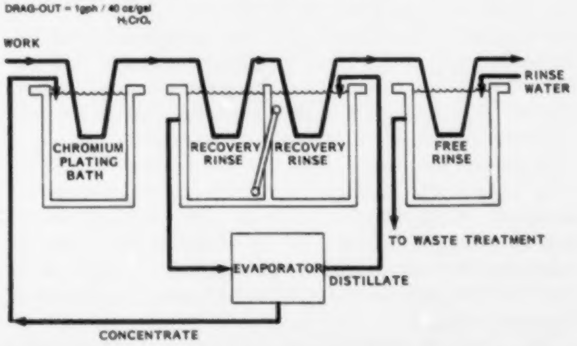

Fig. 2—Open-Loop Evaporative Recovery of Chromium Plating Drag-Out.

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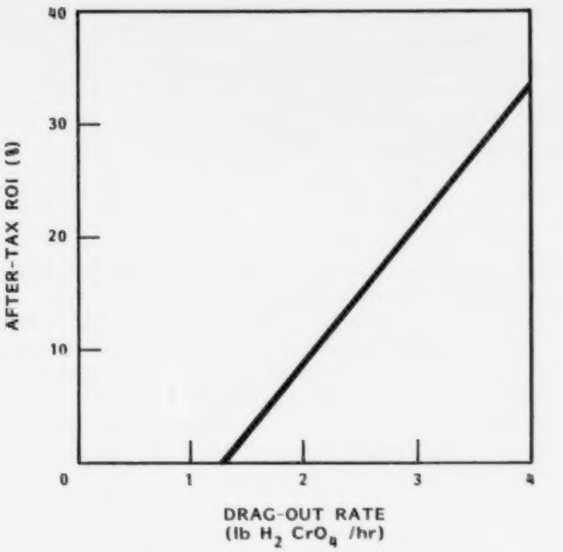
Evaporators, which are available in materials of construction suitable for non-corrosive or highly corrosive applications, have been demonstrated for recovery of chemical dragout for virtually every plating solution in commercial use today. Despite this versatility, reliable operation and process simplicity, the use of evaporators for dragout recovery has been limited to plating operations with high dragout rates, due mainly to the considerably savings needed to justify the high cost of installing and operating conventional evaporative recovery systems.

Figure 3 illustrates this limitation by comparing the return on investment of an evaporative recovery system to the quantity of chemical drag-out from a chromium plating operation. In this analysis, investment cost for a 25 gallon per hour evaporator was assumed to total \$30,000 and the unit depreciated over 10 years; energy cost equal to \$4 per million Btu's and typical labor and maintenance costs were used to determine operating costs. Savings were based on raw material recovery, wastewater treatment cost reductions and reductions in solids waste quantities. These savings totalled \$1.80 per pound of chromic acid (H_2CrO_4) recovered. Using this basis, a reasonable return on investment is achieved for drag-out rates above three pounds of chromic acid per hour. For plating baths with drag-out rates below two pounds per hour of chromic acid, installation of this recovery system is not economically feasible.



Basis

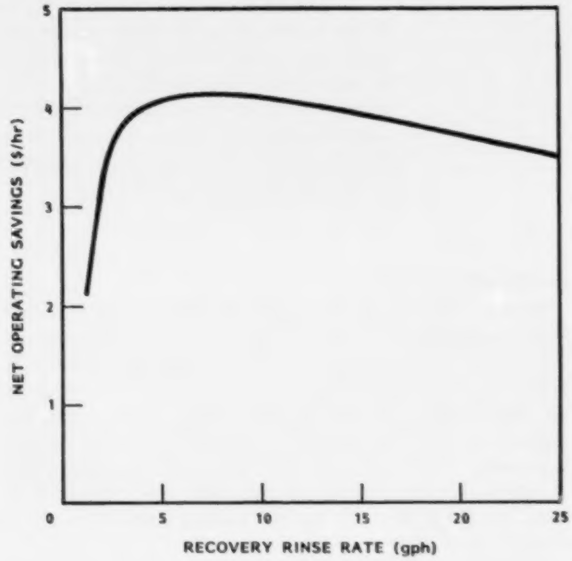
\$30,000 investment required
for 25 gph evaporator Energy
cost equals \$4/10⁶ btu
Operation 4000 hr/year
Tax rate is 48% of profit

Fig. 3—Drag-Out Recovery Investment Justification as a Fuction of Drag-Out Rate.

It should be pointed out that tax credits associated with investments in pollution control hardware were not included in the above analysis. The credits would improve the economics of investments that would otherwise be marginal; however, a plating operation with low drag-out rates would still not be able to justify such a recovery system.

The range of applications for evaporative recovery systems could be increased significantly if low cost, low capacity units were available. Referring back to the open-loop recovery system shown in Figure 2, what would be the optimum recovery rinse rate in terms net operating savings?

Net operating savings are defined as the value of recovered chemicals and savings in pollution control costs minus the utility cost to operate the evaporator. As shown in Figure 4, based on an energy cost of \$4 per million Btu's savings are maximized at a recovery rinse rate of six gallons per hour. Or looking at it another way, savings are maximized when 6 gallons of rinse water are evaporated and recycled per gallon of dragout. At that rinse rate, 95 percent of the chemical drag-out is recovered and the energy cost associated with the evaporative duty is less than 25 cents per hour.



Basis

Net savings are defined as savings
in recovered raw materials and pollu-
tion control costs minus utility cost
to operate the evaporator.
Energy cost = \$4/10⁶ BTU

Fig. 4—Optimum Recovery Rinse Rate for Open-Loop Recovery System Shown in Figure 2.

Considering the low evaporative rate needed to gain the lion's hare of the dragout losses from this plating step, it would seem unnecessary to purchase a continuous automated evaporative recovery system. These systems typically have minimum size units with capacities of 25 gallons per hour and installed cost in the range of \$25,000 to \$35,000.

Two low cost evaporative recovery techniques are available. They are direct drag-out recovery by recycle of rinse water to the plating bath to make up for surface evaporation losses and the use of low cost, low capacity batch evaporators to concentrate rinse water for recycle.

Recycle of rinse water to the plating bath to make up for surface evaporation losses (Figure 5) is a form of evaporative recovery that has the advantage of minimal investment requirements. For high temperature baths operated in the 150° F temperature range, sufficient evaporation will occur to reclaim the bulk of the dragout. Use of air agitation in the plating tank will increase the surface evaporation rate. Make-up to the bath can be done manually or automated as shown in Figure 5. In the Figure, level sensors control make-up to the bath and

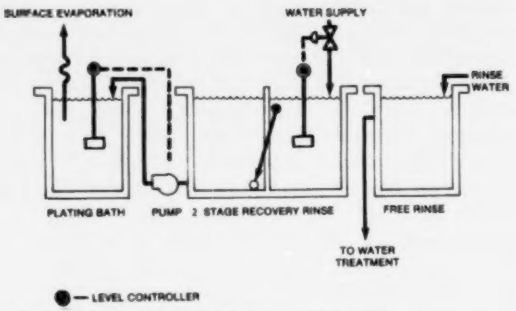

SURFACE EVAPORATION
WATER SUPPLY
RINSE WATER
PLATING BATH
PUMP
2 STAGE RECOVERY RINSE
FREE RINSE
TO WATER TREATMENT
● — LEVEL CONTROLLER

Fig. 5—Automatic Rinse and Recycle Recovery System.

additions of fresh rinse water.

For baths where the surface evaporation rate is not sufficient to effectively utilize rinse and recycle recovery, a simple batch evaporator, or still, can be used to enhance recovery.

Stills of the sort recommended for this application can be constructed in the shop or purchased. Figure 6 shows a home made unit used to augment surface evaporation from a nickel plating solution. Steam supplied to the coil heats the solution, which humidifies air bubbled through the solution. A convenient recovery procedure using a batch evaporator of this type is presented in Figure 7.

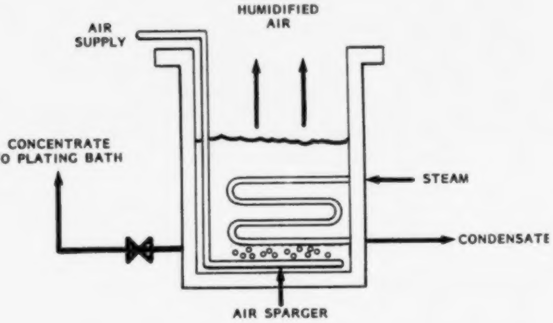
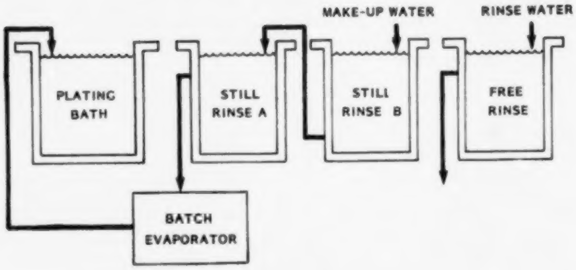

HUMIDIFIED AIR
AIR SUPPLY
CONCENTRATE TO PLATING BATH
STEAM
CONDENSATE
AIR SPARGER

Fig. 6—Batch Atmospheric Evaporator.


MAKE-UP WATER
RINSE WATER
PLATING BATH
STILL RINSE A
STILL RINSE B
FREE RINSE
BATCH EVAPORATOR

TRANSFER SEQUENCE
1) TRANSFER EVAPORATOR CONCENTRATION TO PLATING BATH
2) TRANSFER STILL RINSE A TO EVAPORATOR
3) TRANSFER STILL RINSE B TO STILL RINSE A
4) ADD FRESH WATER TO STILL RINSE B

Fig. 7—Batch Recovery System Daily Sequence.

For baths with no surface evaporation losses, the evaporator can be fed a blend of rinse water and plating solution to provide the volume in the plating bath for recycle of the concentrate.

Figure 8 is a schematic of an atmospheric concentrator which sells commercially for approximately $6000. The unit has an evaporative rate between five to ten gph. Although this and the unit shown in Figure 6 may not be energy efficient, the fact that they consume only small amounts of energy makes insignificant the cost penalty associated with the inefficiency.

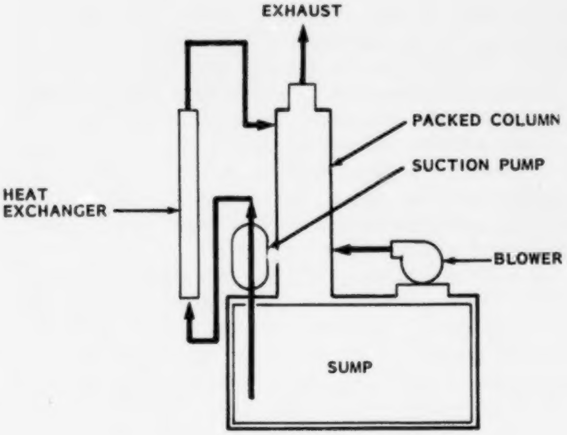

EXHAUST
PACKED COLUMN
SUCTION PUMP
HEAT EXCHANGER
BLOWER
SUMP

Fig. 8—Batch Atmospheric Evaporator.

In summary, the use of evaporation is still the most reliable, versatile, and easily understood separation process for recovery of dragout. Cost effective utilization of evaporative recovery can be realized in many cases by direct drag-out recovery to make up for plating bath surface evaporation or where necessary, augmenting surface evaporation with low cost, low capacity batch evaporators.

ION EXCHANGE

Ion exchange is a versatile separation process which has found application within the metal finishing industry for:

- Concentration of plating chemical dragout for recycle to plating bath and rinse water reuse
- End-of-pipe wastewater treatment
- Mixed wastewater deionization and water reuse
- Polishing after conventional wastewater treatment to reduce the concentration of dissolved metals
- Purification of spent acids
- Water supply deionization

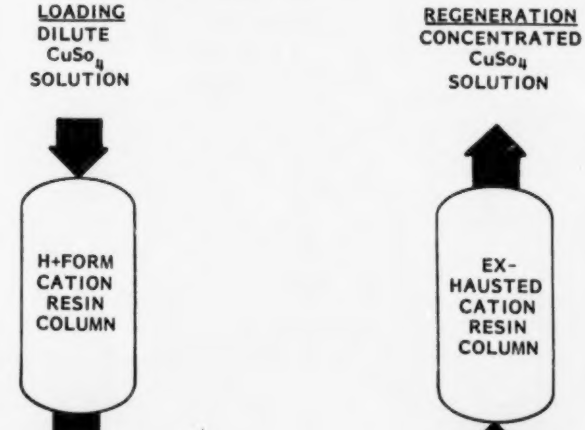

LOADING
DILUTE CuSo4 SOLUTION
REGENERATION
CONCENTRATED CuSo4 SOLUTION
H+FORM CATION RESIN COLUMN
EX-HAUSTED CATION RESIN COLUMN
DILUTE H2SO4 SOLUTION
10%H2SO4 SOLUTION

Fig. 9—Ion Exchange Concentration of Copper Sulfate Solution.

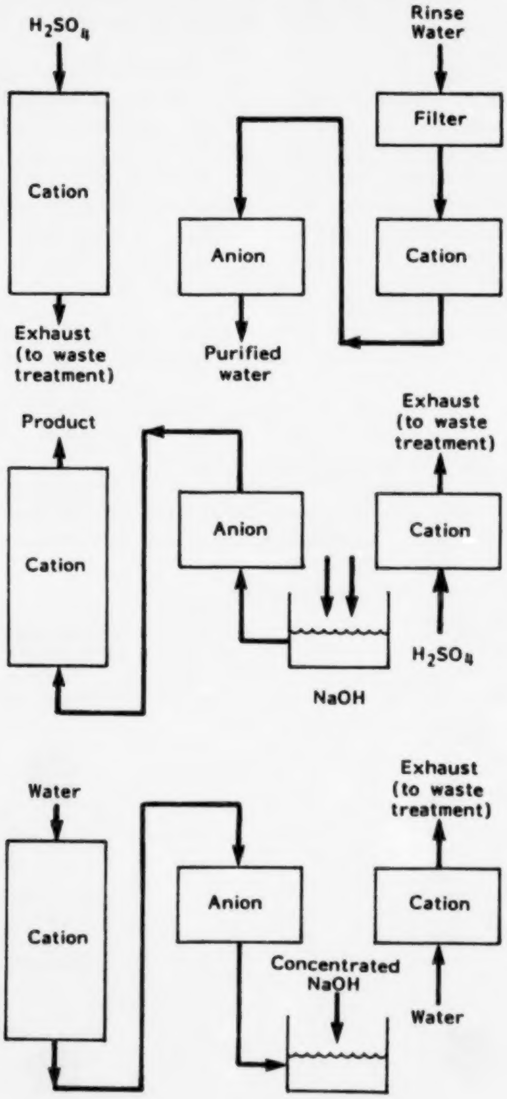
Ion exchange is a reversible process where a solution is passed through a bed of resin particles which exchange ions attached to the solid resin matrix for similarly charged ions in the solution. In Figure 9, the exchange is between copper ions in solution for hydrogen ions attached to the cation resin. When the resin's exchange capacity has been exhausted, the bed is regenerated with a suitable solution, in this case sulfuric acid, which elutes the collected copper ions and returns the resin bed to its original form. The copper in the feed solution has not been changed chemically, but it has been concentrated into a much smaller volume.

The early ion exchange systems were of the fixed bed variety. These systems were often made continuous by duplexing of the columns to allow for sustained operation during regeneration. The significant cost and complexity of such fixed-bed systems minimized their application for recovery of plating chemicals from rinse solutions.

The development of the Reciprocating Flow Ion Exchanger enhanced the potential application of ion exchange for plating drag-out recovery by providing a lower cost, compact, automated ion exchange recovery system. This unit was especially developed for purifying the bleed stream of a large volume solution, such as the overflow from an electroplater's rinse tank. The operating principal of a reciprocating flow unit for chromic acid recovery is presented in Figure 10. The unit operates on the principle that for the short period it goes off-stream for regeneration, the build-up of contaminants in the rinse system is negligible. The advantages of this unit over fixed bed systems for such applications include:

- Reduced equipment cost (due primarily to the small resin volume required)
- The unit automatically regenerates itself minimizing labor requirements
- Compact size

Reciprocating flow units are currently being utilized for dragout recovery from chromium, copper, and nickel plating rinses, for purification of spent process acids and for mixed wastewater deionization.



ON STREAM (LOADING)

Rinse water is pumped from the chromium plating rinse tanks through the prefilter to remove any solids, then through the first cation bed where cationic contaminants (e.g., Fe^{+3}, Cr^{+3}) are removed by the resin. The rinse water then passes through the anion bed where the chromate ions are removed. The purified rinse is returned to the rinse system. While the unit is on stream, the second cation bed is regenerated.

REGENERATION

After a preset period of time, the unit goes off stream. The first cation bed is regenerated with sulfuric acid and washed with water. The anion bed is regenerated with sodium hydroxide and the effluent is passed through the second cation bed; the concentrated chromic acid solution resulting is returned to the plating tank.

WASHING

The three beds are then washed with water, as the product from the anion bed contains the excess caustic used in the regeneration step, it is mixed with concentrated NaOH and used in the next regeneration cycle. The unit then goes back on stream.

Fig. 10—Reciprocating Flow Ion Exchanger Operating Cycle.

The use of ion exchange for mixed wastewater deionization and reuse is an application which could see considerably more use in the future.

Figure 11 shows a commercially operated wastewater deionization treatment system which has been operated since 1975. The system was designed to process 100 gpm of plating wastewater containing copper, nickel, and trivalent and hexavalent chromium. The wastewater also contains trace amounts of cyanide.

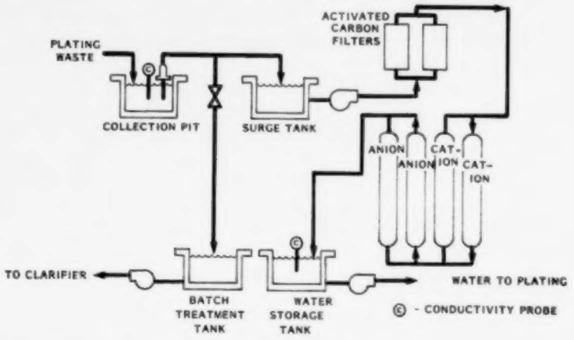


Fig. 11—Ion Exchange Wastewater Reuse System.

The system features:

- Activated carbon prefilters to trap oil, free chlorine and suspended solids which might foul the resin bed
- A conductivity probe to monitor the purity of the treated water. When the dissolved solids content of the treated water reaches a certain concentration, the flow is diverted to the off-stream columns and the spent columns are regenerated. A column usually operates for three days prior to regeneration.
- A batch treatment tank is used to treat the regenerant solutions. The batch treatment sequence employs successive steps for cyanide oxidation, chromium reduction, and metal precipitation. The treated solution is processed in the flocculation/clarification sequence used to process the plants non-plating wastestreams.
- A conductivity probe is installed on the treatment system feed. If the wastewater is grossly contaminated, the flow is diverted to the batch treatment tank. Treatment of wastes with high concentration of contaminants by ion exchange is economically unfavorable.

This system processes approximately 300,000 gallons of water per cycle. Each cycle produces approximately 400 gallons of acid regenerant, 600 gallons of caustic regenerant and 6000 gallons of wash water; these solutions are discharged to the batch treatment tank. Deionized process water is used for wash water and its discharge acts as a purge to control the build up of any contaminants not removed by the recycle system. Treatment of the pollutants is not eliminated; however, the chemical destruction system is reduced to a single batch tank. The plant reports that the cost to operate the ion exchange system is $60,000 per year.

The use of this type treatment for selected rinse waters can be justified by savings in water and sewer fees and reduction of the investment required for pollution control hardware. Figure 12 compares the chemical cost of a wastewater deionization and reuse system to the chemical cost associated with the conventional treatment approach. The chemical cost for the ion exchange process includes regeneration chemicals plus the cost to precipitate the copper from the regenerants and assumes recycle of 90 percent of the incoming wastewater. The chemical consumption for the conventional treatment approach, includes:

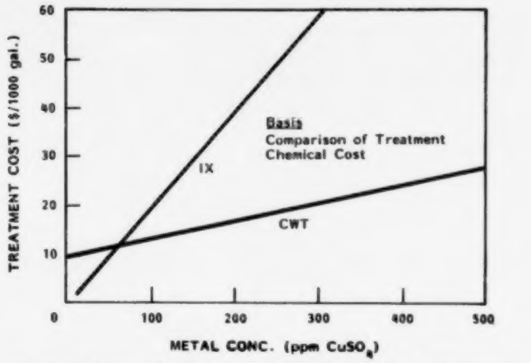


Fig. 12—Treatment Chemical Cost Comparison: Wastewater Deionization/Reuse Versus Conventional Waste Treatment.

- Lime to precipitate the copper
- Lime to raise the water pH from neutral to 9.0
- Lime to react with naturally occuring alkalinity in the water supply
- Polyelectrolyte for flocculating the wastewater solids.

As shown, for treatment consisting solely of pH adjustment and flocculation to separate metals as insoluble hydroxides, ion exchange compares favorably only for treating very dilute solutions. Treatment of wastewater typical of the metal finishing industry is less costly by conventional chemical processes.

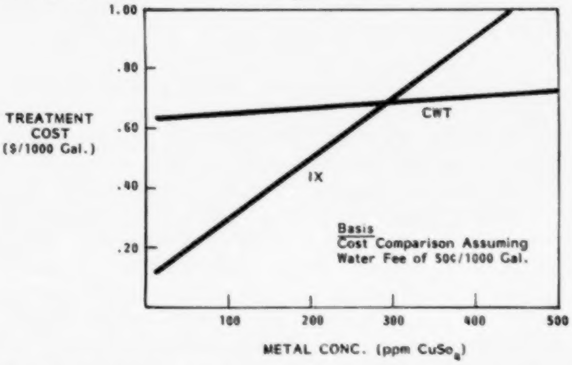


Fig. 13—Treatment Chemical and Water Use Cost Comparison: Wastewater Deionization/Reuse Versus Conventional Waste Treatment.

Figure 13 presents a similar analysis, but includes a water use fee equal to fifty cents per thousand gallons of water consumed. In this case, an ion exchange system achieving 90 percent water reuse is more economical for treatment of waste streams up to a metal salt concentration of 250 ppm. With the water recycle credit, deionization of selected rinse waters compares favorably with a chemical destruct system For wastewaters containing polutants requiring more extensive treatment, such as those containing hexavalent chromium, ion exchange compares favorably up to higher concentration levels. Treatment of spent concentrates or grossly contaminates wastes should still be accomplished by conventional treatment techniques.

A wastewate deionization reuse system is particulary attractive for plants which have access to a centralized treatment facility for industrial wastes. The central

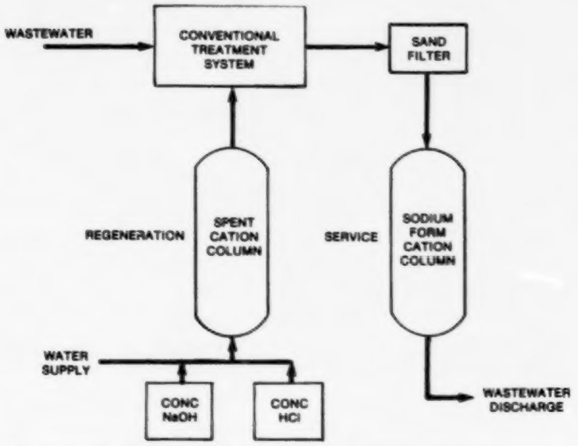


Fig. 14—Ion Exchange Polishing After Conventional Treatment.

concentrates and spent processing solutions, eliminating the need for any chemical destruction system.

Another application of ion exchange which could receive increased attention for plants unable to achieve required metal concentration discharge limitations is ion exchange polishing after an existing conventional treatment system. (Figure 14) In some areas, plants discharging wastewater directly into receiving waters are being required to achieve effluent metal concentrations in the 0.1 to 0.2 part per million range.

It is unlikely that these concentration levels can be consistently achieved with a metal hydroxide precipitation/clarification/filtration treatment sequence. An ion exchange polishing, using fairly recently developed chelated cation exchange resins, offers a relatively inexpensive means of achieving effluent metal concentrations in the tenth of a part per million range. These chelated resins have a high selectivity for heavy metal cations in the presence of high concentrations of similarly charged sodium, calcium, or magnesium ions. As an example, augmenting a 30 gpm treatment system with an ion exchange polishing system consisting of two columns, each containing seven cubic feet of cation resin, would cost approximately $20,000. Based on an inlet metal concentration of five parts per million and a conservative estimate of resin capacity, each column could process approximately 330,000 gallons of wastewater prior to regeneration.

Assuming continuous operation 24 hours per day, this corresponds to a regeneration frequency of approximately one column every 8 days. Each regeneration would consume 50 gallons of 10% hydrochloric acid and 60 gallons of 10% caustic soda. These solutions would be treated in the conventional treatment system. Chemical cost for regeneration chemicals would amount to only $17.00 per cycle, or approximately $2.00 per day.

MEMBRANE PROCESSES

Membrane processes utilized in the plating industry include reverse osmosis and electrodialysis. Beyond the similarity of using membranes to achieve the separation of water from dissolved solids, both processes are continuous, come in compact modular units, and have low operating costs over a broad range of loading conditions.

Both processes are being applied for drag-out recovery from plating rinse waters. Pre-engineered packaged units cost $25,000 to $35,000 installed. As such, their application is limited to baths with high drag-out rates. A significant saving in replacement chemicals and treatment costs is needed to justify the initial investment.

Reverse osmosis (Figure 15) is a pressure driven membrane separation process where water molecules are preferentially forced through the microscopic pores of a semi-parmeable membrane. The salt molecules dissolved in the water solution, due to their larger size, are restricted from passage through the membrane pores.

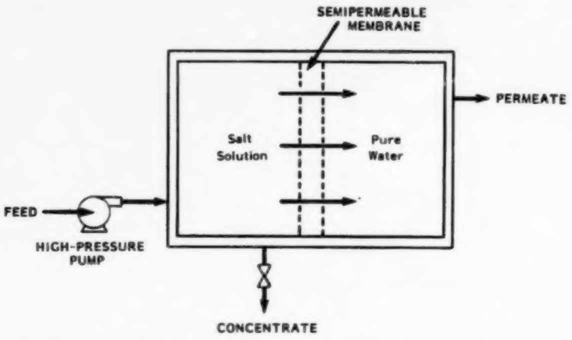


Fig. 15—Simplified Reverse Osmosis Schematic.

Reverse osmosis units using a cellulose acetate membrane have been successfully applied to concentrate the dragout from plating solutions; both the concentrate and the purified water are recycled. Cellulose acetate membranes are not stable over a broad pH range and the primary application is for Watts Nickel Plating Baths, which provide a mild chemical environment. Other dragout recovery applications include acid copper, acid zinc, and chromic acid baths, however, pretreatment to assure that the membranes are not exposed to low pH conditions is needed for these applications.

Reverse osmosis is also limited in the degree of concentration it can achieve. Consequently, for applications where plating baths have minimum surface evaporation, suplemental evaporation of the concentrate may be required prior to its recycle.

Another application of reverse osmosis which has received recent attention is mixed wastewater purification with recycle of the permeate and treatment of the concentrate. The application is attractive because of the continuous operation and low operating cost characteristics of RO units. However, it is questionable whether RO membrane systems are sufficiently reliable or durable to operate under the variable conditions characteristic of mixed wastewaters. Potential problems include membrane fouling due to contaminants in the feed stream or precipitation of salts in the concentrate, membrane deterioration due to the chemical environment, and high levels of dissolved solids in the permeate. As newer, more chemically durable membranes are developed and field proven, this application may see greater implementation.

In electrodialysis, contaminated rinse water is passed through a network of alternately spaced anion permeable and cation permeable membranes (Figure 16). An electrical potential is applied across the membranes to provide the driving force for the ion passage through the membranes. This configuration creates channels which are alternately concentrated or diluted of ions. The major difference compared to RO is that, like ion exchange, the

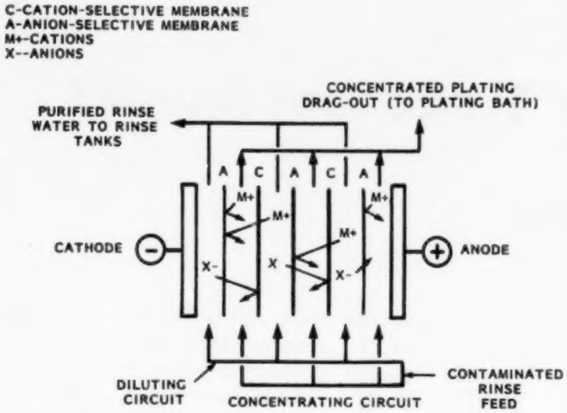

C-CATION-SELECTIVE MEMBRANE
A-ANION-SELECTIVE MEMBRANE
M+-CATIONS
X--ANIONS
CONCENTRATED PLATING DRAG-OUT (TO PLATING BATH)
PURIFIED RINSE WATER TO RINSE TANKS
A
C
A
C
A
M+
M+
M+
M+
CATHODE
ANODE
X-
X
X-
DILUTING CIRCUIT
CONCENTRATING CIRCUIT
CONTAMINATED RINSE FEED

Fig. 16—Electrodialysis Flow Schematic.

separation of water from salt is achieved by selective removal of the salt, not concentration by driving off the water. Unlike ion exchange, the units are continuous and the only operating cost is for electricity, about 7 kW.

The membranes used in the electrodialysis stack are essentially thin sheets of the same polymeric network used to make ion exchange resins. A cation permeable membrane will have negatively charged, fixed ion sites which will attract the positively charged cations into the membrane, but repel negatively charged anions. The cations will continue through the membrane due to the electrical potential that is applied.

Like ion exchange resins, the electrodialysis membranes are durable to most chemical environments. They are membranes, however, and are subject to fouling if the potential exists. Current applications include the recovery of dragout from rinses after nickel, acid zinc, zinc cyanide, and chromium plating processes.

Does Recovery Reduce Treatment Needs?

F. A. Steward*

INTRODUCTION

The answer to the question posed by the title is a resounding YES. However, the author is strongly of the opinion that companies purchasing treatment facilities should look for the reduction only in operating costs, treatment chemicals, labor, and sludge disposal.

There seems to be a wide spread impression that less waste treatment capacity need be provided if recovery equipment is to be installed. We strongly recommend that this approach not be taken. The treatment system should be designed with adequate capacity to handle upsets, recovery system downtime, accidents, etc. Payback on the recovery equipment should come only in the operating savings.

This paper will present data from an actual case to illustrate the kind of problems which can arise.

By way of background, our company supplied a waste treatment system for a new plating facility that made extensive use of recovery technology. After installation, it was found to be impossible to consistently maintain the required effluent quality. Investigation showed that the problem was almost entirely a result of inability to handle the sludge quantities being generated. Modification of the plant to increase sludge handling capacity is now underway.

For a variety of reasons, the company that installed the new facility has asked to remain anonymous. In spite of the fact that this detracts from the authenticity of the case history, we felt the insight gained through experience at this plant would be of interest and value to the industry.

THE PRODUCTION PLANT

The new electroplating facility was ideally suited to materials recovery. It was a brand new plant designed with a single, automated, high-production plating line to put a decorative chromium finish on plastic pieces. The plant is clean, modern, and has a very steady rate of production averaging about 1,500 ft^2 per hour. The process steps in the plating line are as follows:

Plastic Etch
Electroless Nickel
Nickel Strike
Copper Plate
Semi-bright Nickel
Bright Nickel/Dur Ni Nickel
Chromium Plate
Chromium Strip
Nickel Strip

IN − RECOVERED = WASTE

With the exception of the strippers, copper plate and electroless nickel, each process bath was followed by recovery rinses connected to recovery units. Given the design flow through the recovery rinses, and using classical rinsing calculations, approximately 99% of the dragout from each major process is available for recovery. Overflow from the chrome recovery rinses goes to separate evaporators. The etch recovery loop includes a cation exchanger for removal of trivalent chrome. The nickel recovery rinses are tied into two separate ion exchange systems.

DESIGN BASIS

Waste Loads

The sales engineer on the job assumed that 95% of the dragout would be recovered from each of those processes followed by recovery rinses. The following table lists the total waste loads calculated to be present if no recovery were practiced, together with those expected to reach the treatment system.

	No-Recovery	Expected Load
Cr	52.0 lb/hr	3.4 lb/hr
Ni	14.4	2.6
Cu	3.8	3.8
	70.2 lb/hr	9.8 lb/hr

The figures in this table, as well as those throughout the report, are based on quantities of dry sludge which would be generated. They are calculated by taking the hydroxides of each of the metals. The No-Recovery figures were calculated by using estimates of the dragout to be expected for the production rate on the machine. The figures under Expected Load include the dragout from the two strippers, electroless nickel, and the copper plating bath as well as 5% of the anticipated dragout from the recoverable processes.

It was agreed during the initial sales discussions that extra waste resulting from downtime on the recovery equipment would be hauled away be a contract waste hauling company.

Press Capacity

The filter press included in the original design had the following capacity:

$$\frac{2.5\ \text{ft}^3/\text{cycle} \times 30\%\ \text{Dry Solids} \times 80\ \text{lb/ft}^3}{2\ \text{hr/cycle}} = 30\ \text{lb/hr}$$

Thus, the sludge dewatering equipment had approximately three times the capacity theoretically assumed to be needed. This was felt adequate to provide

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for inert solids and extra loading due to minor upsets. As mentioned earlier, operation after start-up indicated that the filter press was completely inadequate for the loads reaching the treatment system. As a result, a series of field investigations was conducted.

FIELD INVESTIGATIONS

On October 16, 1978, engineers from our company visited the plant and spent a full day investigating the sources of the extra load. Numerous leaks, drips, and spills were observed as can be expected during start-up of a major production operation. Approximately six weeks later, a second visit and two days of investigation by two engineers indicated that many of the initial start-up problems had been resolved, but that the treatment system was still overloaded with sludge. Samples collected during this visit indicated that overflows from the rinses on the plating line could not account for the quantities of sludge being experienced.

After several meetings and discussions, extra filter plates were ordered for the press to approximately double its capacity. In early January, a run of the treatment system was attempted for four consecutive days of twenty-four hour operation. During this period, an attempt was made at a material balance around the entire plant. While we have long realized that an accurate material balance in a plating operation is extremely difficult, we were particularly frustrated in this case by an inability to get samples from various points in the recovery loops. As one example, tanks in these loops would overfill and spill onto the floor. It was impossible to accurately estimate the volume lost, and the concentration was variable from time to time. In addition, several of the waste lines from the various recovery units were manifolded together so as to make separate sampling impossible without piping modifications.

Based on the results of the study in January, it was agreed to run a performance demonstration during which the recovery units would be operated under the supervision of factory representatives from the suppliers and the treatment system would be operated under our supervision. This demonstration was to run four days, twenty-four hours per day. The ultimate conclusion was that the expanded filter press was only marginally capable of handling the waste load under such idealized conditions.

Waste Sources

The sources of un-anticipated load on the treatment system which were identified during the four field investigations deserve mention, since they illustrate the types of problems common in metal finishing plants.

- Hoses in rinse tanks
- Downtime
- Rinse tank dumps
- Losses of recovery liquors
- Wastes from recovery units

As is common in many production operations, and almost inevitable during start-up, the plating operators would use hoses to supplement the flow of water to various rinse tanks to keep them "clean." In some cases, this extra flow was causing an overflow over the rim of the tanks onto the floor. In other cases it was overloading the recovery systems causing losses from them as discussed later.

Over the period of time our engineers spent in the plant, there was never any time that all of the recovery units were operating. During the final four day demonstration, downtime was very minor. However, it is unlikely that such close attention and supervision can be provided in a typical operating plant. Designers and purchasers of major industrial processes are keenly aware of the impact of downtime. It is a factor which is recognized and anticipated. Such must also be the case with recovery systems in metal finishing operations.

As a carry-over from operating practices prior to the use of recovery and waste treatment equipment, the operators in this plant would periodically dump the contents of the rinse tanks to allow them to remove parts which dropped off racks. Obviously, such a practice places extra hydraulic and chemical load on the treatment system simply as a result of the normal free-flowing rinses. However, dumps of the recovery rinses are particularly troublesome. The first recovery rinse after the chromium processes is a highly concentrated liquor. The periodic dump represented a loss equivalent to many hours of production.

Those same concentrated liquors mentioned above can be easily lost from the loop en route to the recovery equipment. Even more significant is the loss of concentrated liquor after it has been processed by the recovery equipment. In either case, the loss can occur as a result of tank overflows due to misadjustment of timers, failure of level controls or pumps, or due to the operator increasing the flow at the recovery tanks on the plating line. There were actually cases when the loads reaching the waste treatment system were higher than would have been experienced if there were no recovery units at all!

Each of the recovery systems includes a "waste" line and a purchaser should pay careful attention to the quantities which will leave by this route under ideal conditions and also to the variables which can affect that quantity. Quite often the tuning adjustments can be critical and require close attention from the laboratory and operating people. To be used to best effect, a recovery loop should be regularly analyzed by the laboratory as though it were another process.

MATERIAL BALANCE

Anyone who has attempted to strike a reasonable balance around various parts of a metal finishing operation will appreciate the difficulty. The primary equation needing to be solved in this particular case can be stated as:

We found it impossible to get a reasonable fix on the quantities being recovered due to the numerous variables involved. Levels and concentrations were changing constantly in tanks. Units were operating or down on varying schedules. Tanks would periodically overflow onto the floor.

A reasonable estimate on the IN factor is available from calculations based on dragout rates, and these can be confirmed by analytical checks on the flow of water going to recovery and/or treatment.

The third factor, WASTE, can be judged by collecting the filter case generated and analyzing a composite sample.

IN

Two different spot checks were made to confirm the assumptions used to calculate dragout in the initial design work. In the first, the recovery rinse after the etch bath was sampled for analysis and the flow rate checked carefully. The analysis showed 26.4 g/l CrO_3 which, at a flow of 120 gal/hr, corresponds to 26.4 lb/hr of chromium hydroxide. This corresponds to 30 lb/hr as calculated from the assumed dragout at 7.5 gal/hr from the etch bath alone.

A second spot check is based on analysis of the treated wastewater flow as it enters the clarifier. The suspended solids concentration was 938 mg/l at 145 gal/min on the flow meter and 1,050 mg/l at 140 gal/min. These values correspond to total dry sludge readings of 68 and 73 lb/hr respectively. These readings were taken at a time when all recovery systems were out of operation. These figures correspond to the calculated value mentioned earlier of 70.2 lb/hr total sludge generation.

In both cases the agreement is reasonably good, supporting the assumptions used for the dragout calculations. Better correlation cannot be expected given the variables in a metal finishing operation and waste treatment system.

OUT

During the last four day demonstration run, the filter cake collected averaged 49 lb/hr (dry). Collection of a true composite from a mass of filter cakes is a difficult chore, and was not attempted. Nevertheless, an average of the analyses of several filter cakes taken at different times during the run is as follows:

$Cr(OH)_3$ - 29.9% - 14.6 lb/hr
$Ni(OH)_2$ - 12.1% - 5.9 lb/hr

Since production was virtually constant during the entire four day run, the recovery systems were kept operating at close to 100%, and under good control, and rinse dumps were avoided, the composition of the filter cakes could be expected to be reasonably constant. Therefore, within the level of accuracy which can be expected from such a material balance, these figures are felt to be representative.

RECOVERED

The rate of chromium recovery can be expressed as follows:

$$\frac{52 - 14.6}{52 - 12} = \frac{37.4}{40} = 93.5\%$$

The figure of 12 lb/hr corresponds to the "unrecoverable" chrome which includes dragout from the stripper and the trivalent chrome in the dragout from the etch bath.

Similarly, the recovery rate for nickel can be expressed as:

$$\frac{14.4 - 5.9}{14.4 - 2.0} = \frac{8.5}{12.4} = 68.5\%$$

In this case, the un-recoverable nickel includes the dragout from the nickel stripper and the electroless nickel bath.

It is important to note that the indicated recovery rates were maintained during the four day demonstration at which time the recovery units were under the careful attention of factory representatives. These rates would be decreased in a normal production plant by the various factors discussed earlier under Waste Sources.

CONCLUSIONS AND RECOMMENDATIONS

Forecast Versus Reality

This paper illustrates numerous ways in which the actual results realized with recovery equipment can vary from the original expectations. While it is true that most of these can be covered by a shrewd evaluation of what can be expected, it is also true that there are many variables in other production plants which have not been covered in this case history.

Housekeeping Burden

It is clearly false economy to invest in recovery facilities unless careful housekeeping procedures are instituted. Spills, dumps, and overflows can lose as much as the recovery equipment is attempting to reclaim.

Manpower Needs

Recovery equipment will not operate without attention. It is an axiom in process design that each piece of moving equipment needs men to maintain it and men to operate and adjust it. We have seen literally dozens of cases where sophisticated recovery equipment sits idle because the plant doesn't "have time" to keep it operating. When doing your initial payback calculations, be sure to include realistic estimates of the time required for operators to tweak the controls, maintenance people to keep everything running, and laboratory people to periodically analyze the recovery rinses and concentrate streams.

Waste Treatment System Capacity

We strongly recommend that a waste treatment system be installed with adequate capacity to handle all anticipated loads from the metal finishing operation. This allows the plant to continue producing during downtime on recovery equipment and also gives the extra capacity to handle the accidents and upsets which are inevitable in a complex processing operation.

Regeneration of Waste Chromic Acid Etching Solutions in an Industrial-Scale Research Unit

L. C. George, D. M. Soboroff and A. A. Cochran*

ABSTRACT

Substantial amounts of chromium are lost in various surface-finishing operations and pollution problems are created when spent solutions containing hexavalent chromium and sulfuric acid are discarded. Laboratory research has shown that these spent etching solutions can be regenerated in a diaphragm cell. When the spent solution is placed in the anode chamber, most of the Cr^{3+}, *produced during etching operations, is oxidized to* Cr^{6+}. *Impurity metals dissolved during the etching operation are transferred to the catholyte. When waste brass etchants are treated, about one-third of the copper and zinc is removed. The energy consumption is less than 9 kwhr/kg of sodium dichromate regenerated. Similar results are obtained with spent printed-circuit-board etchants and rinse waters from plastic etching operations. An industrial-scale research unit capable of oxidizing up to 0.5 kg/hr of trivalent chromium has been operated to demonstrate the viability of the recycling techniques. Regenerated brass etchants evaluated by two companies equaled or exceeded the performance of fresh etchants.*

INTRODUCTION

The mission of the Bureau of Mines is to ensure the continued viability of the domestic minerals and minerals economy and the maintenance of an adequate mineral base, so that the Nation's economic, social, strategic, and environmental needs can be better served. Part of the work done in support of this mission has as its goal secondary resource recovery and effecting pollution abatement. In accordance with these activities, the objective of this investigation has been to develop a method for regenerating and recycling spent chromium-bearing process liquors that are currently discarded as wastes.

Solutions containing Cr^{6+} and sulfuric acid are used in brass finishing, printed circuit board etching, preparation of plastic for plating, anodizing, and various other surface treatments. As the solutions are used, Cr^{6+} is reduced to Cr^{3+}, the dissolved solids content increases, and the acid concentration decreases. The action of these solutions on a copper substrate can be represented by the following reaction:

$$Cr_2O_7^{2-} + 3\ Cu + 14\ H^+ \rightarrow 2\ Cr^{3+} + 3\ Cu^{2+} + 7\ H_2O$$

A spent printed circuit etchant, for example, would contain considerable amounts of Cu^{2+}, Cr^{3+}, and Cr^{6+}. A spent brass etchant would contain zinc in addition to these components. Actual plant practice involves adding sodium dichromate to the process tank to replenish the Cr^{6+} that has been reduced and to make up losses from drag-out. The entire tank is dumped when the etchant no longer performs properly despite additions. The decision to dump or add reagents is often made on the basis of the appearance of the part being etched and not on a chemical analysis of the etchant. Technology for ultimate disposal of these wastes usually involves the reduction of the remaining Cr^{6+} to Cr^{3+} followed by base addition to precipitate chromium and other metallic hydroxides. The resulting sludges are then used for landfill.

The disposal of these solutions in this manner wastes valuable resources and is cause for environmental concern. All U.S. primary chromium production is from imported ores. More than 2.7×10^7 kg of chromium are used annually for metal surface treatment and corrosion control measures (4). The minimal recovery technology practiced by the metal finishing industry results in the discarding of valuable secondary resources. In addition, chromium has long been recognized as a major pollution problem and its disposal is regulated by the EPA (9). Landfill areas suitable for metal hydroxide sludges are becoming scarce, and collection, treatment, and disposal by waste contractors is expensive (3).

For these reasons, it is desirable to develop a method that would effect economical, in-plant recycling of spent chromic acid-sulfuric acid etchants. Recycling such etchants would result in a major reduction of chromium-containing effluents, thus reducing the costs of waste treatment and disposal. Further, recycling these etchants would conserve chromium, thus reducing process costs by reducing chromium purchases.

Several electrolysis methods have been proposed for

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recycling etching solutions. Lancy (5) used an electrodialysis cell fitted with a cation-selective membrane to separate copper from chromic acid. The copper was recovered by electrowinning in a separate unit. Tirrell (8) suggested reduction of the Cr^{6+} content of a spent etchant to Cr^{3+} in the cathode chamber of a diaphragm cell. When all the Cr^{6+} was reduced, the copper was plated out at the cathode. The copper-depleted solution was then used as the anolyte, and the Cr^{3+} was oxidized back to Cr^{6+}. Fujii (1) suggested a similar approach for exhausted chromium-plating solutions. Gussack (2) used a diaphragm cell to reoxidize Cr^{3+} to Cr^{6+} in spent plastic etching solutions.

The research described herein differs from previous work in that the chromium is oxidized and contaminating metals are removed in a one-step process that minimizes the use of electrical energy. The authors have previously reported (6-7) small scale results where spent brass etchants, spent printed circuit board etchants, and rinse water from plastic etching operations, covering a wide range of compositions, were regenerated. The apparatus for regeneration and recycling employed a diaphragm cell fitted with a cation-selective membrane. The solutions were placed in the anode chamber where Cr^{3+} was oxidized to Cr^{6+}. The acid concentration increased to the normal value for a comparable fresh solution. A portion of the contaminating metals migrated through the membrane into the catholyte. Essentially all the copper that migrated was recovered at the cathode. Regenerated brass etchants evaluated by two companies equaled or exceeded the performance of fresh etchants; they were superior in the removal of red stain oxide.

This paper describes the process research unit (PRU) which was developed to regenerate and recycle spent etching solutions on an industrial scale.

EXPERIMENTAL PROCEDURES

Spent Etchants

The spent etchants used in the PRU were obtained from brass finishing operations. The solutions were originally prepared from sodium dichromate and sulfuric acid. The compositions of these solutions are given in Table I. Elements detected in trace amounts by spectrographic analysis included Ag, Al, Ca, Fe, Mg, Mn, Pb, Si, and Sn.

TABLE I
SPENT ETCHANT COMPOSITION

	Composition, g/L					
Sample	Cr^{3+}	Cr^{6+}	Cu	Zn	SO_4^{2-}	pH value
A	24	8.3	30	13	168	0.4
B	25	6.8	33	13	191	0.4

The Process Research Unit

A flow diagram for the regeneration and recycling process is shown in Figure 1. Spent etchant is withdrawn from the etching tank and pumped through a 1 to 3 μm pore size wound polypropylene cartridge filter. The filter step reduces membrane plugging by fine particles and thus lowers cell resistance. The filtered solution is then pumped into the anode chambers of a diaphragm cell.

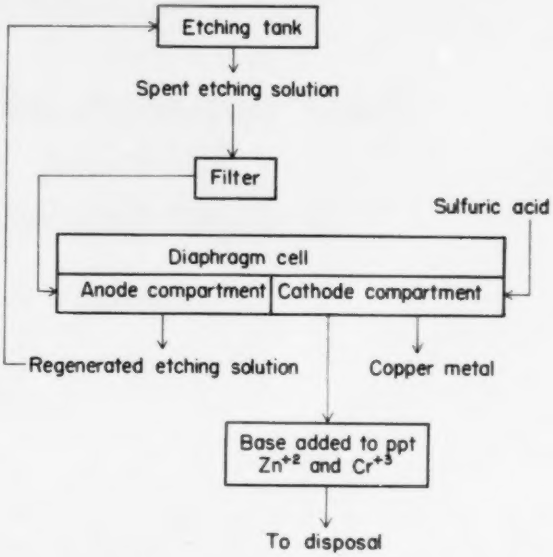

Fig. 1—Flow diagram for regeneration and recycling of spent etchants.

Figure 2 is a schematic representation of a diaphragm cell containing one anode chamber and two cathode chambers. The anode chamber is fitted with Nafion[5] 427 cation-selective membranes to allow ion migration without mixing the anolyte (the spent etchant) and catholyte (180 g/l sulfuric acid). There is space for five anode chambers in the diaphragm cell used in the PRU. The chambers are constructed of Plexiglas. One-sixteenth-inch thick Viton gaskets are used to seal the membrane between the chamber's flange and frame. When assembled, the chambers are contained in a 0.9 × 0.9 × 0.9 meter polypropylene tank which forms the cathode chamber. A lead-6 pct antimony anodes is positioned in the anode chamber at the left. Two copper cathodes (alloy 110) are positioned on either side of the chamber. The remaining electrodes have been removed so that the other anode chambers are visible. The ratio of anode area to cathode area to membrane area is 1:1:1.

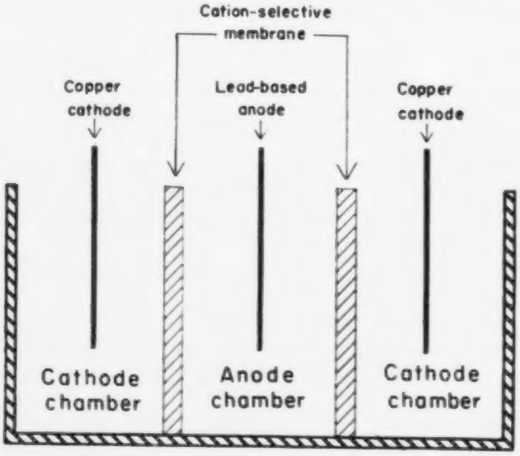

Fig. 2—Diaphragm cell.

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[5] Referenced to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

Cathode current density is 2.15 amp/dm^2. At full capacity, the cell requires ~1,200 amp at ~3.2 volts.

The PRU contains a intank filter unit, an etchant holding tank, a control panel, and a second etchant holding tank. The diaphragm cell is located behind the control panel. The pumps above each holding tank feed filtered etchant into the anode chambers. The pump above the control panel removes regenerated etchant from all anode chambers. The catholyte is circulated using a pump located behind the panel. The hood above the diaphragm cell removes hydrogen, oxygen, and chromic acid mist generated by the cell.

RESULTS AND DISCUSSION

Table II summarizes the results in three PRU tests. The PRU was operated with only two anode chambers in place for tests 1 and 2. Five anode chambers were used in test 3. The values in parentheses in the second column are extrapolations to the flow rate for five chambers. For the first day of each test, the PRU was run in a static mode (no etchant flow) to oxidize most of the Cr^{3+}. For the remainder of the test, spent etchant was fed at the rate indicated. The data in Table II represents flow conditions.

The power consumption figures indicate that about 13¢ worth of power is about $2.40. The rate of production of sodium dichromate increased with increasing flow rate.

The catholyte used for Test 1 was reused in Tests 2 and 3. From an analysis of electrode efficiencies during start-up and analysis of the product during the flow portions of each trial, it appears that reuse of the catholyte is not detrimental. During extended operation of the PRU. A bleed stream will have to be taken from the catholyte. The volume of this stream is estimated to be no more than 20 pct of the volume of etchant (of similar composition to that given in Table I) processed. This stream contains no Cr^{6+} and is far less concentrated in Cr^{3+}, copper, and zinc than the spent etchant. It may be disposed of using neutralization and precipitation technology already in place in most finishing operations.

Copper powder (minus 100- plus 200-mesh) was recovered from the cathodes. The powder adhered to the cathode as long as current was flowing. The material contained 85 to 90 pct copper. The major impurity is oxygen. Traces of Ag, Al, Ca, Cr, Mg, Pb, Si, Sn, and Zn are present. To show that the product could be converted to a usable form, 2 pct carbon was added and it was melted, without agglomeration, in an induction furnace. Ninety-five pct of the copper was recovered as an ingot containing 99.7 pct Cu, 0.01 pct C, and traces of Ag, Mn, Pb, Sb, and Sn.

Previously reported bench-scale tests and Table II show that as the flow rate is increased the percentage Cr^{3+} oxidized decreases by a relatively small amount. Thus, the cost of regeneration decreases as the requirements for metal impurity removal decrease, owing to the shorter retention time required. An examination of the results for Test 2 (Table II) shows that the flow rate, and consequently the amount of Cr^{6+} produced, could be nearly doubled if it was only necessary to remove ~20 pct of the copper and zinc.

There are two modes of etchant regeneration possible with the PRU:

1. The etchant may be used until completely spent and then regenerated. After regeneration, the solution would have to be diluted to the proper operating level. This is because the total chromium concentration is greatly increased due to sodium dichromate additions to make up for the Cr^{6+} reduced during the etching operation.

2. The regeneration system may operate continuously in direct connection with the etching tank. The temporary loss of Cr^{6+} by reduction to Cr^{6+} would no longer have to be made up with chemical additions. The specific gravity and viscosity of the etchant would be lowered, thus drag-out would be minimized.

Bench scale and PRU tests have shown that operation in mode 1 is feasible. Regenerated etchants evaluated by two brass companies performed as well as or better than fresh solutions.

For successful operation in mode 2, the regeneration technique must necessarily operate at lower etchant concentrations, similar to freshly made etching solution. In bench-scale tests using 1 volume of a brass etchant (similar to samples A and B) diluted with 6 volumes of water, Cr^{3+} oxidation, copper and zinc removal, and efficiency were equal to or better than what is reported for the concentrated etchant in table II.

SUMMARY

The technical feasibility of regenerating and recycling spent brass etchants on a large scale has been demonstrated. Using a diaphragm cell, 88 to 96 pct of the Cr^{3+} was oxidized to Cr^{6+} and significant portions of the contaminating metals were removed. Results of evaluations of regenerated etchants by industry were excellent.

TABLE II
RESULTS OF PRU TESTS 1, 2, AND 3

Test	*Flow rate (l/hr)*	*Cr^{3+} oxidation (pct)*	*Cu removal (pct)*	*Zn removal (pct)*	*Cr lost to catholyte (pct)*	*Energy consumption (kwhr/kg $Na_2Cr_2O_7 \cdot 2H_2O$)*	*$Na_2Cr_2O_7 \cdot 2H_2O$ produced, kg/hr*	*Anode efficiency*	*Duration, days*
1[1]	2.6 (6.5)	>96	41	41	11	8.6	0.43	19	3
2[1]	5.7 (14.3)	88	20	23	4	5.7	.70	31	3
3[2]	7.3	92	31	28	5	8.0	.48	21	7

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[1] Sample A is feed material.
[2] Sample B is feed material.

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Liquid Ion Exchange In Metal Recovery and Recycling

Lawrence V. Gallacher*

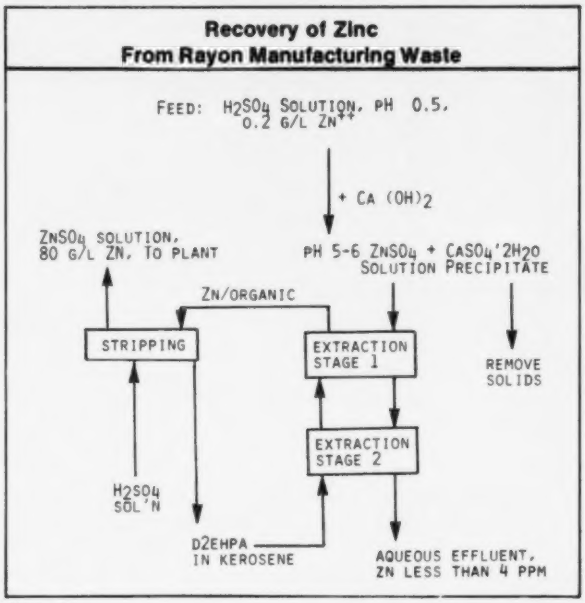
Liquid ion exchange is a relatively new technique which combines the concepts of ion exchange and liquid-liquid extraction for the removal and recovery of metal ions from aqueous streams. Thr growing need for this technology today is the result of many factors, including government discharge regulations, rising metal values and the necessity for treating increasingly dilute solutions.

The electroplating industry in particular is finding it more and more difficult to deal with the problems of waste treatment and disposal, and at the same time, the economic need to regenerate and recycle valuable metal solutions. We are becoming increasingly aware of the fact that accepted treatment methods like the removal of heavy metals from waste streams by generating mixed hydroxide, carbonate or sulfide sludge are ultimately undesirable. They generate potentially hazardous solid wastes, both in the legal and the technical sense, and waste valuable resources. Ion exchange technology, particularly liquid ion exchange, offers an effective approach to eliminate the solid waste and recycle the metal values where they will be most valuable.

I would like to start this presentation by describing four actual applications of liquid ion exchange in metal recovery. Then we will cover the basic principles of liquid ion exchange, the major types of reagents , how they can be applied to solve specific problems and what the future holds.

Case I. (Figure 1)

A strongly acidic solution of 0.2 grams per liter zinc in sulfuric acid is generated by a rayon plant. If the zinc is precipitated by neutralizing to pH 9.5 with caustic soda, a slimy, intractable sludge is generated. If lime is used, a tremendous volume of calcium sulfate precipitate is produced, mixed with a very small quantity of zinc hydroxide, and the result is a difficult solid disposal problem. The problem is solved by first treating the effluent with lime, leaving it weakly acidic and precipitating calcium sulfate only. The zinc solution is then mixed in two stages with a solution of di-2-ethylhexylphosphoric acid (D2EHPA) in kerosene to reduce the zinc concentration in the effluent to less than 4 ppm. The organic extract is stripped with a very low volume ratio of sulfuric acid solution to regenerate the D2EHPA and produce a zinc sulfate solution containing 80 g/l which can be reused in the plant.


Recovery of Zinc From Rayon Manufacturing Waste

FEED: H_2SO_4 SOLUTION, PH 0.5, 0.2 G/L ZN^{++}
+ CA $(OH)_2$
$ZNSO_4$ SOLUTION, 80 G/L ZN, TO PLANT
PH 5-6 $ZNSO_4$ + $CASO_4 \cdot 2H_2O$
SOLUTION PRECIPITATE
ZN/ORGANIC
STRIPPING
EXTRACTION STAGE 1
REMOVE SOLIDS
EXTRACTION STAGE 2
H_2SO_4 SOL'N
D2EHPA IN KEROSENE
AQUEOUS EFFLUENT, ZN LESS THAN 4 PPM

Figure 1.

Case 2. (Figure 2)

Mixed metal waste consisting of scrap, lathe turnings, mill shavings and the like contain recoverable Mo, W, Co, Fe and Ni. The process involves five steps:

1. Pyrometallurgical pretreatment, which converts the refractory metals Mo and W into their carbides.
2. Electrolytic dissolution of Fe, Co, and Ni (using diaphragm cells and calcium chloride electrolyte solution with anodic dissolution of the metals) followed by partial stripping to concentrate the $CaCl_2$ electrolyte.
3. Separation of Fe, Co, and Ni by extraction with a high molecular weight amine.
4. Stripping the cobalt/iron organic extract with the weakly-acidic condensate from step (3).
5. Cathodic deposition of Co and Ni in separate half cells. The stripped electrolyte then goes to step (2).

The process produces a Ni/Fe mixture and a Co/Fe mixture, which doesn't affect the market value of the Ni or Co significantly. There is no gaseous or liquid discharge.

Case 3. (Figure 3)

An ammoniacal leach liquor containing 12.8 g/l Cu, 29.2 g/l Zn and 110 g/l NH_3 at pH 10.1 was mixed in 3

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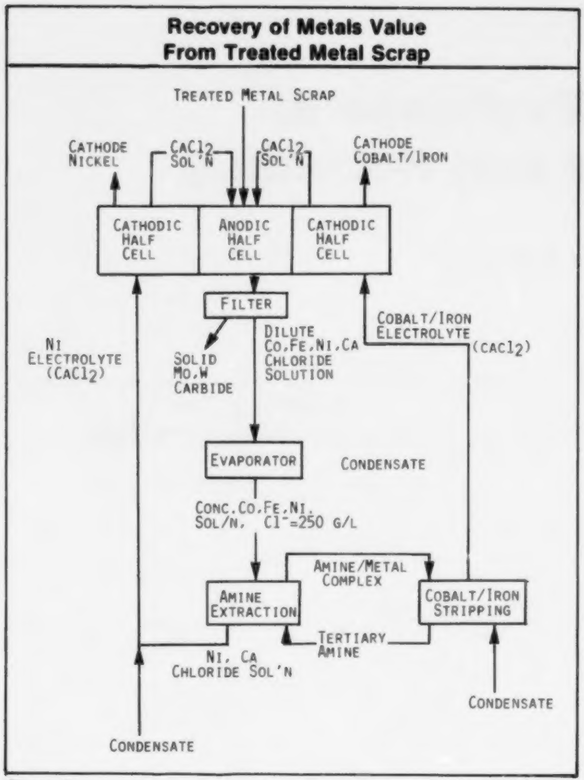
Recovery of Metals Value From Treated Metal Scrap
TREATED METAL SCRAP
CATHODE NICKEL
CACl2 SOL'N
CACl2 SOL'N
CATHODE COBALT/IRON
CATHODIC HALF CELL
ANODIC HALF CELL
CATHODIC HALF CELL
FILTER
COBALT/IRON ELECTROLYTE
(CACl2)
NI ELECTROLYTE (CACl2)
SOLID MO,W CARBIDE
DILUTE CO,FE,NI,CA CHLORIDE SOLUTION
EVAPORATOR
CONDENSATE
CONC.CO,FE,NI, SOL/N, Cl⁻=250 G/L
AMINE/METAL COMPLEX
AMINE EXTRACTION
COBALT/IRON STRIPPING
TERTIARY AMINE
NI, CA CHLORIDE SOL'N
CONDENSATE
CONDENSATE

Figure 2.

counter-current extraction stages with an equal volumetric flow of a 38% solution of an alkyl beta-diketone in kerosene. The copper was quantitatively extracted into the organic phase, but no zinc or ammonia were extracted. The organic extract was then washed with a very small volume of dilute sulfuric acid (26.5 g/l) to remove traces of ammonia and was stripped in 2 stages with an equal volume of solution containing 39 g/l H_2SO_4 and 54.8 g/l Cu. The stripping acid was finally passed through an electrowinning cell to recover the copper.

Case 4. (Figure 4)

A crude phosphoric acid stream containing 58% H_3PO_4, 0.3 g/l Ca^{++}, 2.1 g/l Mg^{++}, 10.0 g/l Al^{+++} and 9.5 g/l Fe^{+++} is extracted with 5 volumes of an extractant mixture consisting of 12% di-2-ethylhexylphosphoric acid (D2EHPA) and 19% dinonylnaphthalene sulfonic acid (DNNSA) in kerosene at 54° C. In a single stage, 4.4% of the phosphoric acid, 92% of the Ca^{+++}, 42% of the Mg^{++} and 12% of the Al^{+++} are extracted. The extraction is carried through several countercurrent stages to remove essentially all of the Ca^{++} and Mg^{++} and much of the Al^{+++}. The extract is then "scrubbed" with a 20% phosphoric acid from the organic phase, and the scrub solution is later combined with the feed and recycled. The extract is stripped with 1/10 volume of 10% sulfuric acid in 2 stages at 55° C to regenerate the extractant. A portion of the strip solution is removed from the system to be neutralized and fresh make-up acid is added to make fresh stripping acid solution. The phosphoric acid product produced by this process is suitable for conversion to high-quality super phosphoric acid liquid fertilizers.

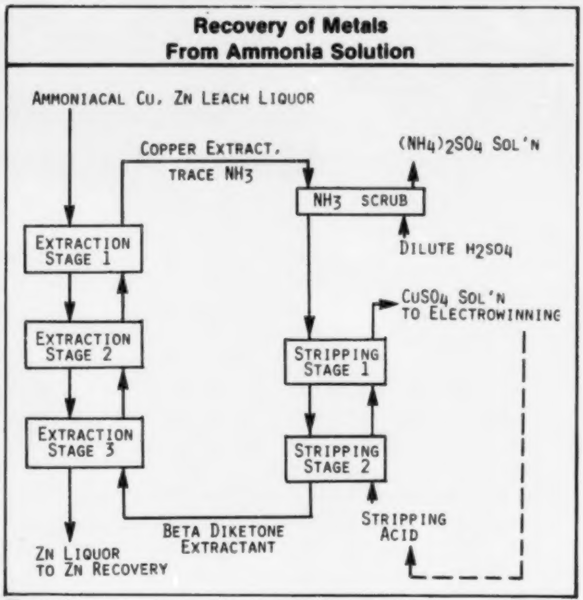
Recovery of Metals From Ammonia Solution
AMMONIACAL CU, ZN LEACH LIQUOR
COPPER EXTRACT, TRACE NH3
(NH4)2SO4 SOL'N
NH3 SCRUB
DILUTE H2SO4
EXTRACTION STAGE 1
EXTRACTION STAGE 2
EXTRACTION STAGE 3
CuSO4 SOL'N TO ELECTROWINNING
STRIPPING STAGE 1
STRIPPING STAGE 2
STRIPPING ACID
BETA DIKETONE EXTRACTANT
ZN LIQUOR TO ZN RECOVERY

Figure 3.

The four cases just described are actual examples of liquid ion exchange processes which have been operated on a large scale. They illustrate several key points we would like to make in this paper, namely:

1. Recovery of metals by liquid ion exchange is a realistic and economically viable concept.
2. There are a number of reagent types available for extracting metals under a number of very different conditions, i.e.:
   - from weak acid leach liquors
   - from relatively concentrated acids
   - from ammoniacal leach solutions
   - as anionic complexes
   - from mixtures containing many metals
3. A "good" process generates little or no secondary waste. Maximum recycling of all streams is utilized.
4. Typical working processes bring a number of chemical and engineering disciplines together.

THE PRINCIPLES OF LIQUID EXCHANGE

Liquid ion exchange is somewhat similar to conventional ion exchange using solid resins in that an aqueous feed solution is contacted (mixed) with an active reagent in a mixing chamber or column. In this operation, ions are extracted from the feed in exchange for hydrogen ions or other transferable ions carried by the liquid ion exchange reagent. The liquid ion exchange reagent is water-insoluble, and is generally used as an "extractant" solution in a hydrocarbon solvent such as kerosene. The actual "exchange" takes place when the aqueous feed is mixed intimately with the extractant, producing an unstable liquid-liquid dispersion of droplets of one phase in the other. At the moment of mixing, the interfacial area is very great, and the exchange process occurs via a three-step mechanism whereby:

1. The hydrated or complexed metal ion diffuses to the aqueous/organic interface,

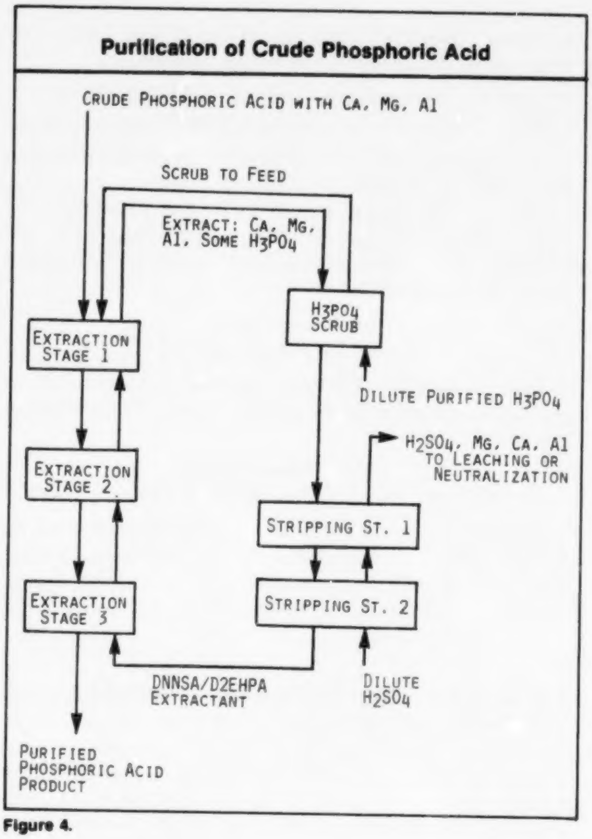
Purification of Crude Phosphoric Acid
CRUDE PHOSPHORIC ACID WITH CA, MG, AL
SCRUB TO FEED
EXTRACT: CA, MG, AL, SOME H_3PO_4
H_3PO_4 SCRUB
DILUTE PURIFIED H_3PO_4
EXTRACTION STAGE 1
EXTRACTION STAGE 2
EXTRACTION STAGE 3
H_2SO_4, MG, CA, AL TO LEACHING OR NEUTRALIZATION
STRIPPING ST. 1
STRIPPING ST. 2
DNNSA/D2EHPA EXTRACTANT
DILUTE H_2SO_4
PURIFIED PHOSPHORIC ACID PRODUCT

Figure 4.

TABLE I
LIQUID ION EXCHANGE PROCESS STEPS

1. Extract metal into organic phase.
2. Strip metal ions from organic phase.
3. Recover the metal and regenerate the stripping solution.

TABLE 2
LIQUID ION EXCHANGE PROCESS CRITERIA

1. The process must achieve the desired result within allowed constraints.
2. All streams in and out and products must be accounted for completely.
3. The extractant system should have good long-term operating characteristics.
4. Interferences must be identified and treated in advance.

2. The ion is stripped (ideally) of its hydration layer and complexes with the liquid ion exchange reagent at the interface, making the interfacial transition, and,
3. The organic/metal complex diffuses into the bulk organic phase. Simultaneously, hydrogen ions or other labile ions associated with the reagent in the organic phase are transferred to the aqueous phase. In fact, the actual exchange takes place at the interface.

Now we have successfully extracted the metal ion into the organic phase. The next step usually is to strip the organic, re-extracting the metal ions with an aqueous stripping solution. In the case of acid extractants, stripping is done with a dilute mineral acid. Often, as in two of the examples, the extractant phase picks up ionic or molecular species in addition to the desired ones, and these are extracted in a "scrubbing" step using a weak reagent before the stripping step.

The final step is to recover the metal itself and regenerate or dispose of the stripping solution. This step is just as important as extraction and stripping, but is frequently given inadequate attention. The easy, but expensive route, is to neutralize the stripping solution and generate a neutral waste stream or sludge. The best approach is one which regenerates the stripping solution and recovers the metal directly, electrolytically or by direct reduction, or as an insoluble salt. (Table I reviews the 3 liquid ion exchange steps).

Perhaps at this point you are wondering why we bother to extract the metal from the aqueous feed into the organic phase, only to re-extract it into a new aqueous phase. This is a good time to enumerate the benefits we can gain from liquid ion exchange beyond simple metal recovery. They are:

a. Increase the metal concentration in the stripping solution relative to the feed. By using high volume ratios of feed to extractant and extract to strip solution, it is possible to increase the final metal concentration up to one hundred fold or more. This can be the key to metal recovery by electrowinning, crystallization, or precipitation.
b. Recover one metal in the presence of others. Frequently, the desired metal is present with a high background level of other unwanted metals, e.g., copper in the presence of ferric iron. In other instances, all of the metals may be valuable, but only one at a time. Selectivity in liquid ion exchange can be obtained by using specific reagents or combinations of reagents, or by making adjustments in feed solutions or stripping solutions. We'll say more about this further on.
c. Recover metal from an ammoniacal solution without the complexed ammonia. Reagents are available which extract Cu^{++}, Ni^{++}, and Zn^{++} from ammoniacal leach solutions without extracting ammonia. The metals can be obtained together or separately by controlling either extraction or stripping conditions.
d. Change the counterion present in the feed to a different one. Sulfate can be exchanged for chloide, for example, by extracting a sulfate feed with an acid extractant and then stripping with dilute hydrochloric acid.

Successful application of liquid ion exchange to metal recovery requires careful attention to certain key details. Before getting into a discussion of reagents, we will briefly review these four criteria, since they are critical in the selection of extraction reagents. (Table 2).

First, the process must achieve the desired result within the allowable conditions of time, temperature, concentrations, pH, equipment and cost. Cost is obviously a paramount consideration. Fast extraction, stripping, and phase separation mean small equipment, small reagent inventory, and low cost. The same is true of high extraction and stripping capacity.

Second, all feed streams, extractants, stripping solutions, and recovered metal values must be accounted for *completely*. A "cradle-to-grave" approach for all streams is essential.

Third, the extractant system should have good long-term operating characteristics. These include chemical stability, good metal-complex solubility, *very* low solubility in feed and stripping solutions, and good phase separation characteristics with no haze. Solubility and haze are the principal causes of extractant losses.

Fourth, interferences must be identified and treated in advance. Interferences can include co-extracted ions which don't strip, oxidation or reduction reactions, solids in the feed, and dissolved organics. For instance, organic additives such as amines or surfactants are likely to be extracted and a gradual deterioration of phase-separation characteristics is likely. Possible answers are to put in a carbon adsorption column before extraction or to strip the impurities afterwards.

TYPES OF LIQUID ION EXCHANGE REAGENTS AND THEIR APPLICATIONS

There are four fundamental classes of reagents used in liquid ion exchange:

1. Acids, which extract cations in exchange for hydrogen ions, ammonium ions, or other metal cations,
2. Chelating agents, which extract cations in exchange for hydrogen ions via highly specific interactions,
3. Amines and quaternary ammonium salts, which extract anions/anionic metal complexes in exchange for anions,
4. Neutral reagents, which function by solvating metal ions directly or by forming complexes with other reagents, which in turn are more effective than either reagent.

I will attempt to describe important members of each class of reagents, their important characteristics, and principal applications.

ACIDS

These are all high molecular weight compounds containing large hydrocarbon groups which render the acids and their salts water-insoluble and also offset the normal surface activity of such materials. Generally speaking, the stronger the acid, the lower the selectivity but the better it extracts at low pH. When acids are used, the exchange of metal ions for hydrogen ions lowers the pH of the aqueous phase. This effect severely limits the metal-loading efficiency of weak acids. One answer is to use the acid in salt form (e.g., Na^+ or NH_4^+); another is to adjust the aqueous pH between stages. Representative acid extractants are described below:

Di-2-ethylhexyl phosphoric acid (D2EHPA)
$(C_8H_{17}O)_2$ P(O)OH (Mobil, King Industries)

A weak acid with good hydrolytic stability. Strong affinity for Fe^{+++}. Good selectivity, dependent on feed pH. Requires use of salt form or buffering to obtain high loadings. Biggest use is in uranium extraction, mixed with trioctyl phosphine oxide. Use as sodium salt in kerosene requires addition of modifiers, e.g., 5% isodecanol, to prevent third phase formation.

Dinonylnaphthalene sulfonic acid (HDNNS)
C_9H_{19} SO_3H C_9H_{19} SYNEX DN (King Industries)

A strong acid with excellent stability at temperatures below 60° C. Extracts well down to pH 1.0 with little selectivity. Selectivity greatly enhanced by combining with other reagents including D2EHPA, LIX 63, SYNEX XB1. Ammonium salt extracts well from ammoniacal solutions.

Carboxylic Acids
R-COOH Versatic (Shell)

Weak acids (See D2EHPA comments). Use in sodium salt form is restricted by solubility and emulsification tendency.

Alkyl Benzotriazoles
R NH N N SYNEX XB-1 (King Industries)

Selectively extracts copper, nickel from neutral to acidic media. Mixtures with sulfonic acids, alkylphosphoric acids, or carboxylic acids have higher selectivity and operate at lower pH.

AMINES AND QUATERNARY AMONIUM SALTS

These reagents are used to extract anions, usually in the form of metal complexes. Stripping is accomplished with aqueous salts or bases. Tertiary amines are most popular, and are used in protonated form in acid medium. Because of protonation, which results from extraction of a mineral acid molecule (H_2SO_4, HCl) from the feed,

$$R_3N + HCl = R_3NH^+Cl^-$$

there is a net transfer of acid to the stripping solution when basic stripping solutions are used. However, phase separation is much better with basic stripping. Quaternary ammonium salts are useful over a wide pH range, even in basic media. However, because they can't be deprotonated, stripping tends to be difficult.

Tertiary Amines

R_3N Alamine (Henkel), Adogen (Ashland)

Biggest use is in uranium recovery, where amines are used to extract the uranyl sulfate complex. Other uses mostly involve extraction of chloride complexes. Some selectivity can be achieved by taking advantage of the fact that some metals extract at lower chloride concentrations than others. For example, at pH 2 and 40° C, Alamine 336 extracts ferric iron at 50 g/l chloride, copper at 100 g/l, and nickel only slightly at 250 g/l. Sensitivity to oxidation in some systems.

Quaternary Ammonium Salts
$R_4N^+X^-$ Aliquat (General Mills), Adogen (Ashland)

Can be used like amines, but do not require low pH. More difficult to strip than amines. Applications tend to be proprietary and not well publicized. Some use in vanadium refining.

DEVELOPING A LIQUID ION EXCHANGE METHOD TO SOLVE SPECIFIC PROBLEMS

Now that we have reviewed important liquid ion exchange reagent characteristics and criteria for applying

TABLE 3
DEVELOPING A LIQUID ION EXCHANGE METHOD

1. Define the problem, the goals and the constraints.
2. Select candidate extractants, stripping solutions and recovery/disposal techniques.
3. Perform laboratory shake-out tests.
4. Modify compositions and conditions as needed and retest.
5. Perform rough cost analysis.
6. Run pilot-scale tests. Look for long-term effects and make necessary corrections.
7. Review cost analysis.
8. Design and construct process.

TABLE 4
LIQUID ION EXCHANGE TROUBLE-SHOOTING-I

Problem	*Solution*
Extraction	
1. Haze after separation Slow phase separation	1. Raise temperature Use reagent additive
2. Solid Formation	2. Use reagent additive Change solvent
3. Low extraction	3. Increase mixing time Increase reagent conc. Increase organic: aqueous volume ratio Raise temperature Use more selective reagent Change solvent Raise Feed, pH Use salt form of extractant (acids)
4. Low selectivity	4. Use more selective reagent Decrease reagent conc. Decrease organic: aqueous volume ratio Change solvent
5. Organic contamination	5. Pretreat Feed: carbon or solvent Scrub stage
6. Unwanted metal or Inorganic Pick-up	6. Scrub stage, Change Conditions Change extractant

TABLE 5
LIQUID ION EXCHANGE TROUBLESHOOTING-II

Problem	*Solution*
Stripping	
1. Haze, slow phase separation	1. Raise temperature Use reagent additive Amines: Strip with base
2. Solid Formation	2. Use proper acid strip for solubility Ammonia contamination: Scrub stage Check interfering metals
3. Incomplete Stripping	3. Increase temperature Increase mixing time Increase reagent concentration Increase aqueous: organic volume ratio

liquid ion exchange, let's consider how to develop a method to solve a specific problem (Table 3).

The first step is to select and map out candidate processes in rough detail giving preference to the simplest approaches, those which show least cost or maximum return and those which lead to maximum recycling and least waste production. Frequently these criteria go hand-in-hand, but often a level of complexity is required to achieve lowest operating cost and waste.

The next step is to perform extraction and stripping "shake-out" tests in the laboratory using graduated cylinders or separatory funnels. We generally start with equal volumes of candidate extractant and feed in a graduated cylinder with a ground-glass stopper. The extractant concentration is adjusted so that if all the metal of interest is extracted, the extractant will load to about 60% of its theoretical capacity based on its molecular weight and the charge on the metal. The solutions are added at room temperature, the graduate is shaken by hand for one minute to form a liquid-liquid dispersion, and then set down to allow the phases to separate. At this point, it is important to note how rapidly the separation occurs, whether there is haze in either phase, and whether there is any solid formation, particularly at the interface. Slow phase separation and haze can usually be alleviated by operating at a higher temperature, or by the addition of certain additives like isodecanol or tributyl phosphate, or a solvent change. Additives can usually solve solids problems. Increased temperature frequently helps the actual extraction as well, but neutral additives and solvent changes as often as not impair extraction and selectivity. Tables 4 and 5 present common problem areas in liquid for exchange present common problem areas in liquid ion exchange processes and potential solutions.

After the liquid phases have separated, the next step is to carefully remove portions of both organic and aqueous phases and analyze them to evaluate the extent of extraction and the selectivity. Suppose that the extent of extraction is good, but the selectivity between two metals is in the right direction but not good enough. Thus, you might be trying to extract iron from a solution containing 50 g/l nickel and 1 g/l iron. Your analysis shows that the extractant takes out 0.5 g/l iron and 2 g/l nickel. This in fact shows good iron selectivity, since 50% of the iron is extracted while only 4% of the nickel is extracted. A situation like this one is usually improved by adding a stage of countercurrent extraction. If 100% of the iron and 10% of the nickel had been extracted the recommendation would be to lower the extractant concentration or the volume ratio of extractant to feed to achieve higher loading of the extractant. Normally, increasing the loading increases the selectivity, essentially crowding out the less preferred ion. If you are extracting with a weak acid and the extraction is very low compared to the theoritical capacity of the acid, the problem may be caused by a drop in feed pH that occurs during extraction due to the transfer of hydrogen ions into the feed. The answer here is to use the acid in salt form or to adjust the feed pH between stages using caustic soda or ammonia. Another cause of low extraction is slow extraction kinetics. This can be checked by repeating the experiment with longer shaking times. If the extraction is slow, that means bigger equipment. Try raising the temperature or adding a reagent like DNNSA or LIX 63 to reduce the interfacial tension (Table 5).

Assuming that we have achieved satisfactory extraction in the shake-out tests the next step is to look at stripping. The same general rules apply here. In addition, if stripping is not satisfactory, increase the concentration of the active acid, base, or salt in the stripping solution. It is also very important to think ahead to the ultimate fate of the stripping solution. For instance, if we want to recover copper by electrowinning from a sulfuric acid stripping solution, we should have a copper concentration of about 50 g/l in the stripping solution (called the pregnant electrolyte in the trade). This can be achieved by maintaining a base level of 40 g/l and going up to 50 g/l in stripping and back to 40 g/l in electrowinning. Other options include: direct use of the strip solution as-is, hot stripping followed by re-crystallization of the metal salt, hydrogen reduction, vacuum stripping of the acid (HCl) and water to leave a metal salt, precipitation, and finally, neutralization and disposal.

Once the process concept has been worked out and demonstrated in the laboratory tests, it is time to take a hard look at the economics. The system should be evaluated for extractant losses due to solubility and haze, for these are very important. Neutralization, make-up, energy and equipment costs should all be estimated to see if the process looks feasible.

If so, the next step is to set up and run the process on a pilot scale long enough to see long-term effects. These may include: decomposition of the reagent and a gradual deterioration in performance, accumulation of trace metal impurities in the extractant phase, accumulation of organic or other impurities from the feed in the extractant, or the development of "curd" (an undetermined solid phase at the interface). Solutions to these problems may not come easily. Slight reagent decomposition or solubility loss can be corrected by partial withdrawal and make-up. Accumulation of unwanted metals ions may require a change in the stripping solution or addition of a scrubbing step. The same is true of organic impurities, or these might require pre-treatment of the feed with a carbon-absorption step or a solvent-extraction step. "Curd" can usually be eliminated satisfactorily by the right additive in the extractant.

FUTURE PROSPECTS FOR LIQUID ION EXCHANGE IN METAL RECOVERY AND RECYCLING

In this paper we have attempted to introduce you to liquid ion exchange principles, showing you a minimum of abstract theory, what can be done and has been done, what reagents are available and what each can do and can't do, and how to work out a process to solve your own problems.

Looking ahead, what does the future hold for this technology? As we see it, the economic and environmental pressures are building rapidly to find better ways to recover metal values from process streams and waste streams. Making metal hydroxide, carbonate or sulfide sludges doesn't look like an acceptable long term answer to the environmental problem and is no answer at all to the economic problem. These sludges are notoriously hard to handle and should go to secure, hazardous-waste landfills, since they always have the potential of releasing toxic concentrations of heavy metals under acid conditions.

Liquid ion exchange is one of several approaches to the recovery of metals, but it appears to have the greatest potential for a general solution to the recovery problem.

There will be difficulties along the way, however. Right now it looks like liquid ion exchange is beginning to acquire recognition as a useful technique. Unfortunately, there have also been some false starts in using it - mostly because of ignorance of available information or not considering the total system. However, the last five years have brought rapid progress in the understanding and utilization of liquid ion exchange techniques in this area, and we are confident that progress will continue. Bear in mind that in other fields like primary copper and uranium refining, liquid ion exchange has played a major role for over five years.

Certain applications look very interesting right now. For example, the mixed metal sludges referred to before can be leached with either sulfuric acid or ammonia to generate feed liquors which certainly can be treated with liquid ion exchange to recover valuable metals like copper, nickel, and zinc separately.

I hope that this presentation has helped to inform you of developments and useful applications in liquid ion exchange.

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Achieving Effluent Criteria—Not Final Answer

A. F. Lisanti and R. Helwick*

Much attention has been given to the treatment of wastewater. Wastewaters are characterized and studies conducted to optimize the treatment processes in order to assure achievement of effluent limitations with the least possible cost. In the treatment of wastewaters, especially from metal finishing plants, metals are precipitated and removed as a sludge. The hauling and disposal of that sludge, however, have not received as much emphasis as that of the wastewater treatment processes. Accordingly, many plants are not equipped with the sludge dewatering facilities or the facilities are not the most cost effective. One reason is that the characteristics of the sludge are not adequately known before the wastewater treatment facilities are installed. With the impending sludge disposal requirements as outlined by the Resource Conservation and Recovery Act and the increasing cost of contract disposal, nevertheless, sludge handling and disposal must be addressed with the same zeal as that afforded to the wastewater treatment processes. The sludge should be characterized and studies made to optimize sludge handling and dewatering systems. In addition, evaluations should be made of sludge disposal alternates including recovery processes. These efforts should reduce the cost of sludge disposal.

Other papers presented at the conference will discuss existing or pending regulatory requirements for sludge disposal. As such, this paper will not address that phase but presents a summary of capital and operating costs currently incurred by representative metal finishing plants for sludge disposal. The plants selected for discussion have been designed using well publicized techniques of inplant wastewater flow reduction and best practical treatment technology. The solids dewatering facilities which include the use of filter presses, vacuum filters and diatomaceous earth type of pressure filters were designed based on an evaluation of alternate schemes and data accumulated in treatability studies.

Table I lists the sludge quantities handled by each of the plants. It tabulates the volume of sludge entering the dewatering process, the solids content of the sludge, the solids content of the cake obtained by the mechanical dewatering equipment and the quantity of cake that must be disposed of.

Plant A referred to in Table I batch treats the wastewater and passes the unsettled slurry through pressure filters precoated with diatomaceous earth. Since filtration of the wastewater is necessary to attain effluent limitations, the use of diatomaceous earth filters not only accomplished that goal but at the same time dewaters the solids. Plant B utilizes a continuous treatment system. Since the concentration of suspended solids generated by the treatment processes is of such a level as to preclude direct filtration and dewatering as in Plant A, the wastewater is clarified before filtering through a diatomaceous earth type of pressure filter. The sludge from the clarification process is conveyed to a thickener. The thickener also receives the diatomaceous earth from the pressure filter. After gravity thickening, the solids are dewatered by a filter press. Plant C treats its rinses in a bath operation. The sludge from this process is mixed with spent concentrated acids which are neutralized and dewatered by a filter press. In Plant D, the wastewater is clarified and the underflow conveyed to a storage tank for subsequent dewatering by a filter press. For Plant E. the underflow of the clarifier is gravity thickened and dewatered by a vacuum filter.

Table 2 lists the construction costs for the total treatment facilities, the cost associated with the sludge equipment including housing for that system and the percentage of the total cost of the treatment facilities associated with the sludge handling and dewatering equipment.

Currently, each of the plants are hauling the dewatered solids to an approved landfill site. Table 3 illustrates the costs incured by each of the plants for disposal of those solids. These costs include the pick-up, hauling and placement charges. As noted in the table, Plant C instead of disposing of its solids in a local approved landfill has the option of hauling the solids to another plant within its corporation for metal reclamation.

As a means of comparing the plants operating costs associated with the treatment of wastewater and the costs applicable to the solids handling and disposal, Table 4 is presented. The costs in this table include an estimate of the manpower devoted to the wastewater and solids handling portion of the treatment system. The costs do not include amortization of the equipment.

As demonstrated by the cost comparisons, the sludge handling and disposal facilities are not only a significant factor in the construction costs for the wastewater treatment facilities, especially for the smaller metal finishing plants, but play a major role in the operating costs. Nevertheless, without the sludge handling and dewatering facilities, the disposal costs for the solids would be significantly increased. For example, Plant C

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generates some 153,600 pounds per week of sludge at a local landfill site would cost about $6,150 per week. By dewatering the solids, the weight of sludge to be disposed of its reduced from 153,600 to 76,200 pounds per week and the disposal cost decreased from $6,150 to $3,050 per week. This savings in disposal cost offers a good payback on the capital investment of the solids dewatering facilities. It is advantageous, then, to not only optimize wastewater treatment processes, but the sludge handling, dewatering and disposal options for each plant.

TABLE 1
SLUDGE QUANTITIES

	Dewatering Method	*Sludge Volume, gpd*	*Solids of Sludge, wt. %*	*Cake Solids, wt. %*	*Quantity of Cake Generated, cu ft/wk*
Plant A	Pressure Filtration (DE)	10,000	0.03	40	13
Plant B	Filter Press	340	9	32	150
Plant C	Filter Press	2,285	15	30	941
Plant D	Filter Press	234	1.9	15	14
Plant E	Vacuum Filtration	1,780	8.7	22	620

TABLE 2
CONSTRUCTION COSTS

	Design Flow, gpd	*Treatment Facilities, $*	*Dewatering Facilities, $*	*% of Total Facilities' Cost For Sludge Handling*
Plant A	25,000	450,000	97,000	21.6
Plant B	238,000	1,900,000	240,000	12.6
Plant C	*4,000	940,300	158,000	16.8

*48% is of spent concentrated acids.

TABLE 3
SLUDGE DISPOSAL COSTS

Costs include hauling and disposal charges

	Quantity of Sludge, tons/mo	*Disposal Cost, $/mo*	*Disposal Method*
Plant A	1.0	1,290	Drummed and hauled to approved landfill
Plant B	12	1,800	Hauled to approved landfill
Plant C	165	13,200	Hauled to approved landfill
*Plant C (Alternate)	165	24,750	Hauled to metal reclamation plant

*Cost are for hauling. Does not include cost of metal recovery nor value of recovered metal.

TABLE 4
OPERATING COST COMPARISON

	Entire Treatment Facilities, $/year	*Solids Dewatering and Disposal Portion, $/year*	*% of Entire Cost For Solids Disposal*
Plant A	34,000	16,000	47.0
Plant B	138,000	50,000	36.2
Plant C	27,860	13,200	47.4

Luncheon Presentation: The Resource Conservation and Recovery Act

Rebecca Hanmer*

It is a pleasure for me to be here and to have this opportunity to share a few thoughts with you on hazardous waste. This is my first formal opportunity to meet with representatives of the metal finishing industry. However, in my former job as Deputy Administrator of EPA's Boston Office, I was keenly aware of the economic importance of the industry in New England and thus interested in the means by which electroplaters were seeking solutions to pollution control requirements.

For years, industry has been dealing with requirements to protect the Nation's air and water. Today, I want to talk with you for a few minutes about the law that closes the loop, The Resource Conservation and Recovery Act: RCRA.

I will give you a brief history of RCRA, provide information about the upcoming regulations, and the EPA Regional Office role, and comment on something I believe to be of overriding importance—especially in this program. That is the need to work together. We need to communicate with each other and with the public. For this new set of requirements and protections - vitally needed - will affect us all.

RCRA became law in 1976 and is structured to ensure that from now on our society takes its hazardous waste management responsibilities more seriously. Unfortunately, it was not until the Act was about two years old, and the Love Canal tragedy forced our attention on the magnitude of the residues of past neglect, that we noticed RCRA's limitations. Except for an imminent hazards provision, the Act does not address critical problems which recently have come to light from a legacy of careless waste management. We know now that there are two hazardous waste problems — The one we have inherited and the one RCRA is intended to solve. We know also that neither can be neglected; except at the cost of the extreme peril to ourselves, our children, and people yet unborn.

We produce 57 million tons of hazardous waste each year. We estimate there are more than 750,000 generators of hazardous wastes, 10,000 transporters, and 30,000 treatment, storage, and disposal facilities. At least 90 percent of the hazardous wastes currently produced are disposed of improperly and unsafely. There are up to 50,000 uncontrolled closed and existing sites.

More than 60,000 chemicals are now in common use in this country; thousands more are registered each week. The adverse effects of mismanaged waste can reach us through direct contact, through the air we breathe, the food we eat and the water we drink. It is of critical importance that we keep waste from seeping into the groundwater. About half of the drinking water supply in this country is taken from groundwater. Twenty percent of the population drinks groundwater untreated.

As you probably know, because EPA failed to produce RCRA regulations within eighteen months as stipulated in the law, civil actions were brought against the Environmental Protection Agency by the State of Illinois, the Environmental Defense Fund, and others. Last October, EPA's Administrator, Doug Costle, in a quarterly affidavit on EPA's progress in developing final regulations, said, "Among the many pressing environmental problems currently facing EPA and the Nation, I consider hazardous waste the most serious."

He also pointed out in the affidavit that we received more comments on RCRA than on any proposed regulations in the history of the Agency. At that time we had 1,200 sets of public comments, some of which were hundreds of pages in length.

At the same time we have been involved in developing RCRA regulations, we have had to begin to deal with the problem of closed and existing uncontrolled sites. Working with the Department of Justice and the states, EPA has initiated a remedial and enforcement program directed against hazardous waste sites which pose substantial risk to public health and the environment. Regional offices have been required to redirect many work years towards this effort. Hundreds of sites have been investigated and a number of major enforcement actions have been initiated by the EPA regions.

To provide funds for the clean-up of abandoned sites and to permit a more rapid response where health and the environment are threatened, EPA developed legislation which was submitted by the President to Congress last June to establish a multi-million dollar "superfund." Hearings on the proposal have been held by several congressional committees, on several different bills and committee mark-up is underway.

But, back to RCRA. The original Federal law was born in 1965. That means we are now on the verge of beginning to move against hazardous waste fifteen years after the first federal law to deal with the solid waste problem was enacted.

In 1970, the Congress amended the solid waste law to call for a comprehensive investigation of hazardous waste management practices in the United States, with formal reports to be submitted to Congress.

It wasn't until 1975 that the need for hazardous waste regulation was acknowledged by important segments of

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industry and public interest groups. A Federal system for such regulations was authorized by the solid waste amendments of 1976 that formed the Resource Conservation and Recovery Act.

Today, we have the law and we have some of the regulations. More regulations will be issued this month, with the final regulations for writing RCRA permits expected in October 1980.

The law allows States to assume delegation of the program, and we are working hard with the States to this end.

What is the role of EPA's Regional Offices in the RCRA program: In brief, we are the implementing part of EPA. The 10 regions will be implementing the RCRA regulations either *directly* or, where State programs have been approved, indirectly through State overview. The direct role consists of:

- Assisting persons to understand the regulations and how different industries are affected
- Monitoring compliance with interim status notification and manifest requirements.
- Enforcing where necessary
- Issuing RCRA permits

We will help States set up RCRA programs and approve State programs where possible to take over the direct tasks. We administer State program grants. After the States take over, we help them with difficult situations and oversee progress. RCRA allows a State to qualify *early* to take the program through *interim* delegation. That means the State can run the RCRA program even if it needs to make some legal or regulation changes in order to get the full delegation. The State must have a program to start out that meets most RCRA requirements and a definite timetable for completing improvements in 2 years.

In Region IV, we estimate 5 of our 8 states now will be able to achieve interim delegation this year.

I've been asked to give you a hint about the upcoming regulations, I believe you talked about this at a morning session, so I will just summarize briefly. EPA has already issued the regulations for the manifest system, which go into effect at the end of October 1980. Regulations defining what a generator is and a public notice explaining the notification procedure were also issued on Feb. 26. On April 30, EPA is going to issue the regulations that define (1) hazardous wastes, (2) set our requirements for States to get authorization for running the program, and (3) contain requirements for hazardous waste treaters, storers and disposers to get interim status pending review for a RCRA permit. The procedures for the RCRA permit program are going to be issued on April 30 as part of the consolidated permit regulations.

I can't give you the definition of hazardous waste in advance of the rules, but you have some idea of the impact on your industry from the proposed regulations of last December. Metal finishing sludges contain elements that will likely fall into the definition of hazardous waste, such as chromium, cadmium and lead. Metal finishing wastes may also fall into the hazardous waste characteristics of ignitability and corrosivity.

Early in May, Washington EPA is going to mail out several hundred thousand packages to names on our list of generators, treaters, transporters, storers and disposers. These packages will tell people how to comply with the notification and interim status requirements.

For generators, transporters, treaters, storers and disposers: these persons must notify the EPA regional office within 90 days after the regulations defining hazardous waste are promulgated (around July 30). Also, treaters, storers and disposers have to submit part of the permit application to receive interim status.

Don't assume, if you don't get a package, that you're off the hook. Persons who generate, transport, treat, store or dispose of hazardous wastes must meet the regulations. EPA regions will be required to enforce against those who don't.

I urge you to attend one of the workshops that are going to be held to explain the regulations. The Washington, DC workshop will be on June 2 and the Chicago workshop will be June 6. The regulations should be published in the first two weeks in May in the *Federal Register*. Regional EPA staff will be learning along with you, and will be able to provide technical advice. EPA Headquarters is also planning to set up training programs to help businesses who may be hard hit to learn about applying. I was delighted to learn that AES is a part of this program.

The arduous, long-term task of dealing with hazardous waste is just beginning. Potentially, there are many things that can be done with hazardous wastes besides burying them into a landfill that will meet RCRA's requirements. As is already recognized in your industry, certain waste can be recycled and sent back for reuse. Other wastes can be used by others without processing. Wastes can be dealt with by incineration, chemical neutralization, separating or blending to yield a useable product or supplemental fuel for firing industrial furnaces, and "Biological destruction," in which micro-organisms consume the hazardous material and render it harmless.

Ideally, disposal should be the procedure of last resort. Since RCRA's regulations will make this procedure much more safe but also more expensive than it's been before, eventually the widespread use of other methods should be achieved. For a good while, however, there is no question that the procedure of last resort will be the procedure of greatest use. Moreover, proper disposal will be needed even years from now when we will have drastically altered our perceptions and practices with regard to wastes. There will still be a great many materials that are too low in value to recycle, too difficult to degrade or to inject into deep wells and too contaminated with nonflammable materials to incinerate.

Proper burial under RCRA will be a far cry from dumping. Serious attention to properly engineered landfills with liners, covers, gas generation techniques and monitoring operations will come into being. The chemical solidification of wastes, now used for only a very small percentage of hazardous materials, will no doubt become more popular. And disposal of the wastes will not end the scrutiny process. Disposal site operators will have to monitor and maintain closed sites for many years to make sure that there is no migration into soil or drinking water supplies. There will be liability for each incident of damage that occurs while the site is operating. And money will have to be set aside to close and maintain inactive sites. Violators will be subjected to serious civil and criminal penalties. RCRA calls for truly drastic changes in the way we deal with wastes.

Yet the entire promise and purpose of the Act would be aborted by the strong and widespread public view that treatment and disposal facilities are all right, provided they are located on another planet or at least on another continent. And that brings us to the common cause between industry and government and the need for a genuine on-going dialogue.

In order to implement RCRA, industry and government are going to have to come together. Our challenge is to show the public that we can maintain our commerce, that we can build and maintain safe, effective hazardous waste management facilities. We must show that we can manufacture and use chemicals and other goods without poisoning our groundwater, without creating a no-man's land, and without shipping our problems to the moon. We are not going to be able, in my view, to force communities to take hazardous waste facilities. We - you and I - are going to have to find incentives to offer these communities. And we're going to have to prove ourselves.

I have no doubt that EPA will be sued on the RCRA regulations. I have no doubt that, as we progress with the law we will discover ways our regulations can be improved. However, I also feel the imperative is with us. There is a level of public concern about hazardous waste that compels EPA - and industry - to act - now.

I'll close with this. In the January issue of Chemical Times and Trends, the chairman of the du Pont Company, Irving S. Shapiro, refers to an ancient Chinese saying which goes like this—"May you live in interesting times." Mr. Shapiro went on to say, "The seventies have been too interesting for comfort, and the eighties may prove more interesting still." Then, he added, "The key to profitable operation in the eighties will be effective communication with governments and other constituents." I think he's right. To make our society work, business has got to talk with government and government with business. Let's keep it *us*.

Thank you.

Resource Conservation and Recovery Act

Kurt W. Riegel*

I must admit that when I was asked to come to Florida to explain the RCRA regulations to members of the American Electroplaters' Society, I felt quite good about the confidence the Environmental Protection Agency had in me. After holding quite a few discussions with people in the electroplating industry, however, and hearing of the practical problems many of you have in disposing of your wastewater treatment sludges, I have come to the conclusion that, in reality, the agency was looking for somebody expendable.

Whatever the motivations behind EPA's sending me here, however, today I am going to try to help you make some sense out of what must be a rather confusing picture to everyone—the hazardous material waste disposal regulations, resulting from the Resource Conservation and Recovery Act—or "RCRA".

I will first go into the basic provisions of RCRA which affect the electroplating industry. Then I will discuss the specific regulations that have been promulgated to date. At the completion of my talk, I will have some time for questions—which I will answer to the best of my ability. Howard Schumacher tells me that there will also be round table sessions in which I and members of the Office of Solid Waste will be available for further discussions.

First of all, I would like to make it clear—and I can speak for all of EPA in this—that we at EPA do realize the importance of the electroplating industry to the United States. There is no doubt that the metal finishing industry is a key link in the industrial strength of the United States. I also want to assure you that I am not going to spend a great deal of time talking about the Love Canal incident with you. I fully realize that there are no electroplaters involved in that very unfortunate situation and I also realize that the wastes from electroplating operations are, in many ways, different from those in the organic chemical industry. I also know that some wastes are more hazardous than other wastes, and that a waste which is hazardous when disposed of by one method may be nonhazardous when disposed of properly.

I also feel that there is another major difference between the electroplating industry and the kind of attitude that led to Love Canal and other very unfortunate situations. I have been briefed on the joint AES/EPA characterization of sludges from your wastewater treatment operations and your continuing effort to determine cost effective but safe methods for disposing of these wastes. I understand that the joint AES/EPA cooperative effort arose from needs expressed at this same conference two years ago. If this conference can produce that type of cooperation between the industry and the Government, I want to say that I am very happy to be a part of it.

Now, what about the need for a national program to control the disposal of wastes? Congress felt there was a need for a national program, and passed the Resource Conservation and Recovery Act of 1976. I think that subsequent events have verified that this nation does need to control how industries dispose of wastes that are hazardous. There are just too many instances of individual corporations or persons acting irresponsibly. Those actions have resulted in tragic effects to people and to the environment. As always, when regulations are needed, it is very difficult to decide just how far the regulations should go, and the agency is trying ernestly to strike an appropriate balance between protection of public health and the environment on the one hand and the burdens on industry on the other. RCRA gave EPA the specific responsibility of defining what wastes really were hazardous, and how they should be controlled. From 1976 until now, the agency has been deeply involved in sorting out the proper methods of control. Key sections of RCRA which apply directly to electroplaters are shown in Table I.

Section 3001 of RCRA required EPA to develop and promulgate criteria for identifying the characteristics of hazardous wastes and the listing of hazardous wastes. In developing these criteria, EPA was instructed to take into account toxicity, persistence and degradability in the environment, the potential for accumulation in tissue, and other factors such as flammability and corrosiveness. Congress also directed EPA to revise these criteria from time to time and to make changes as may be appropriate.

EPA has already proposed criteria for hazardous wastes and many of you have commented on the proposed criteria. These comments and other related

Table 1
Key Sections of Resource Conservation and Recovery Act (RCRA, PL 94-580)

Section	Regulation Number	
3001	261	Criteria for listing as hazardous
3002	262	Standards for generators
3003	263	Standards for transporters
3004	264	Standards for disposal facilities
3005	265	Permits for disposal facilities
3010	266	Preliminary notification requirements

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information are being used to derive the final 3001 regulations. For those of you who were not involved in this stage of the regulatory procedure, we essentially approached the problem of defining hazardous wastes by two proposed methods. First we proposed a list of industries which generated wastes which we felt had the potential for being hazardous. Electroplating wastewater treatment sludges were included on this list. These are the so called categorical listings of hazardous wastes. Second, we proposed a procedure for those wastes that were not listed. For unlisted wastes, generators were obliged to test or otherwise assess their wastes against certain characteristics. One of these characteristics was toxicity, determined through laboratory extraction under specified conditions. The extract was to be analyzed and tested to determine if it is hazardous. Because electroplating sludges were listed as a hazardous waste, the proposed regulations did not require use of the toxicity characteristic and the extraction procedure to designate these wastes as hazardous.

I would like to make clear that the regulations for Section 3001 have not yet been promulgated. They have been proposed only, and the agency has been considering the comments made by the public on these proposed regulations. At one time there was hope that we might have the final promulgated 3001 regulations ready to be presented at this conference; however, the current scheduled date for promulgation for these regulations is now April 30, 1980.

The next two sections—the standards for generators and the standards for transporters—were promulgated on February 26, 1980, and I will discuss them in more detail later. The first phase of the Section 3004 Standards for Disposal Facilities is also scheduled to be promulgated on April 30, as are the Section 3005 permitting procedures regulations, which will be a part of a consolidated permit procedures regulation covering RCRA, National Pollutant Discharge Elimination System (NPDES), and Underground Injection Control (UIC) permits. The first phase of the 3004 standards will establish interim status requirements. The second phase of these standards will set the requirements to be incorporated into permits. These will be promulgated around October 30, 1980, and will become effective six months thereafter.

People in regulatory agencies are limited by law in discussing regulations when the public comment period is closed and the regulations are undergoing final revision. Unfortunately, I am under these restrictions today regarding Sections 3001, 3004 and 3005. This is a government-wide policy and not just an EPA practice. It is part of the administrative law which governs how the federal regulatory agencies interact with the public. It allows the agency to fulfill its obligation to remain fully open to the public for an announced period of time for information that may be used to advantage in establishing a regulation. At the close of the public comment period, a regulatory agency must develop its regulations by concentrating solely upon the information which has been presented, it cannot accept further data or comments.

Today we are free to discuss Sections 3002, 3003, and 3010, since they have been promulgated. We can discuss background and answer general questions related to Sections 3001, 3004 and 3005, but I cannot discuss the specific regulations.

Let's now discuss the Section 3002 regulations which apply to generators of the waste. This section sets forth the responsibility of the generators in the "cradle to grave" control system of hazardous wastes. Section 3002 requires the Administrator of EPA to establish certain standards for generators. First, EPA must establish a manifest system which would assure that the waste is designated for delivery at a permitted storage facility. Second, there must be appropriate containers with proper labels for hazardous waste. Third, there are requirements for record keeping which would identify the quantities and disposition of the hazardous wastes. Fourth, general chemical composition information must be provided to parties who will be transporting, treating, or storing the wastes. The regulations require that, prior to transporting, treating, storing or disposing of any hazardous wastes, the generator must obtain an EPA identification number. This number is to be assigned by the agency after receiving the generator's hazardous waste notification.

Table 2 outlines the responsibilities of generators who ship hazardous wastes offsite.

First, the generator is responsible for preparing a manifest, which must identify the generator, the transporter, and the designated disposal site. In addition there is some required information related to the nature of the waste. The manifest also contains the generator's identification number.

In packaging the waste to be shipped, the generator is responsible for complying with DOT packing requirements which have been concurred on by EPA. The other major responsibility of the shipper is that, if within 35 days he does not receive his signed copy of the manifest by the intended receiver of the waste, he must contact that receiver to determine if the waste was received. If the manifest receipt copy is not received within 45 days, then the generator must file a report with

Table 2
Generators Who Ship Hazardous Wastes Must:

- **Determine if a waste is hazardous**
- **Prepare a manifest**
- **Comply with DOT packaging requirements**
- **Contact the designated receiving facility if receipt copy is not received in 35 days**
- **File an exception report to EPA region if receipt copy is not received in 45 days**
- **File an annual report no later than March 1 of each year**

Table 3
3003 Standards for Transporters

- **Must have an EPA identification number**
- **Signs generator's copy of manifest**
- **Must deliver waste to designated disposal site and receive signed copy of manifest**
- **Can accept only properly packaged wastes**
- **Is responsible for cleaning up any waste discharge or spill**

Table 4
3010 Preliminary Notification of Hazardous Waste Activity

- **All persons engaging in hazardous waste—management activities must notify EPA or states having authorized hazardous waste permit programs**
- **Notification package will be mailed to about 350,000 organizations already identified**
- **Notification forms must be received by EPA within 90 days of promulgation of standards for generators**
- **Failure to receive notification package does not release obligation to notify EPA**

Table 5
Schedule for Promulgation of Remaining Legislation

April	3001	Identification and Listing
February	3002	Generator Standards
February	3003	Transporter Standards
April/Fall	3004	Facility Standards
April	3005	Permit Standards
April	3006	State Authorization Standards
February	3010	Notification Process

the EPA regional office. The other major responsibility is the submission of an annual report to EPA by March 1 which must report all activities related to the shipping of hazardous wastes.

Let's now turn to what was the Section 3003-standards for the transporters. (Table 3)

Like the generators, each transporter of hazardous waste must also have an EPA identification number. The transporter forms a part of the link in the "cradle to the grave" control which is initiated by the manifest filled out by the generator. When picking up hazardous materials for transport, the transporter signs the copy of the manifest which is retained by the generator. He is responsible for delivering the waste to the disposal site designated on the manifest, and must receive a signed copy of the manifest when he delivers the waste to the disposal site. The transporter is required to maintain copies of these manifests in his files for a period of three years. If more than one transporter is involved, generally an additional copy of the manifest must be prepared by the generator for each additional transporter. The first transporter must obtain a signed copy of the manifest from the second transporter. There are some special provisions for hazardous materials delivered by rail or water, so-called bulk shipment. In these instances, a standard waybill or other shipping document which contains all of the manifest information except EPA identification number is considered satisfactory for bulk transfers between shippers.

As I mentioned earlier, the packaging, labeling, and placarding of the hazardous wastes must be performed in accordance with DOT regulations. It is the responsibility of the transporter to accept only properly packaged wastes.

Another item of importance to the transporter is that the transporter is responsible for reporting and cleaning up any spilled wastes.

The disposal site operator is responsible for mailing a copy of the final manifest verifying that the waste was disposed of properly back to the generator. The only exception to this would be when hazardous wastes are being shipped outside the country. When waste leaves the United States, it is the responsibility of the transporter to return to the generator a copy signed by the exporter.

Basically, other than the new manifest system, the transporters will be subject to the same DOT regulations that are currently in effect.

The last section for which regulations have been promulgated are those relating to preliminary notification of hazardous waste activity. (Table 4)

The law requires that all persons engaging in hazardous waste management activity notify EPA. This is not really any different than what took place in the control of water pollution several years ago when the permit program required notification. EPA will be sending out notification packages to about three hundred fifty thousand (350,000) organizations which potentially handle hazardous wastes and will need to file notification forms; these notification forms must be received by EPA within 90 days of promulgation of the RCRA Section 3001 regulations which define what are hazardous wastes. As I mentioned earlier, the 3001 regulations are scheduled to be promulgated on April 30.

The failure to receive a notification package does not release anyone from the obligation to notify EPA. The notification package is being mailed out as help to those who we feel probably should be filing notifications.

In the event that a disposal, treatment, or storage facility does not provide notification, then it will become ineligible for interim status pending issuance of a permit. Without interim status or a permit, a facility cannot legally dispose, treat, or store hazardous wastes. Once you have filed your notification you will receive a verification from EPA which will contain your EPA identification number.

There is a tremendous amount of interest about the quantity of hazardous wastes you must generate before it is required that you apply for an identification number. The Section 3001 proposed regulations had a lower limit on size, and we received many comments on this issue. There is another question about the timing. Suppose you have stopped handling hazardous waste. In that event you would not be required to file the notification. The rule for this is any hazardous wastes handled during the 3-month period immediately prior to the date of filing must be included.

The details of the form and the mailing address for receipt of notification are all included in the handout which was released February 26, 1980. There are several copies available, I believe, from the American Electroplating Society or your local EPA office.

This completes my discussion on the regulations which have been promulgated to date. As I mentioned earlier, a very tight schedule is set for the remaining regulations. (Table 5).

The two key sections which will be of great importance to you and which you should watch for closely are Section 3001, which will define what are hazardous wastes, and Section 3004, which sets standards for disposal of the wastes. The permitting process (Section 3005), of course will also be of great interest.

Report on the Results of the AES/EPA Sludge Characterization Project

Kenneth R. Coulter*

The disposal of waste treatment sludges has become of major concern to the metal finishing industry. This fact became evident at the first of the EPA/AES Conferences in Orlando, Florida in January 1978.

In many areas of North America, due to the lack of knowledge and understanding of the behaviour of these sludges in landfill sites, disposal had become extremely expensive, and, in fact, a virtual impossibility in many instances.

The problems associated with sludge disposal became exacerbated with the introduction by the EPA of a proposed test method, under the Resource Conservation and Recovery Act. This test was designed in such a way as to simulate the conditions under which different types of solid waste would behave, in conjunction with the co-disposal of organic wastes, such as may be found in a sanitary landfill.

The test proposed by the EPA calls for filtering or centrifuging the sludge, and then agitating the remaining solid material for twenty-four hours, with a predetermined amount of water. This is maintained at a pH of 5, using acetic acid. The resultant extract is mixed with the original filtrate from the original sample, and the concentrations of various materials are compared to the limitations for these materials as prescribed by the EPA. These concentrations are generally established at ten times the drinking water standard.

The materials of concern to the metal finishing industry with the proposed limitations are shown in Table I.

TABLE I
PROPOSED HAZARD LIMIT

	mg/l
Chromium	0.5
Cadmium	0.1
Lead	0.5
Arsenic	0.5
Mercury	0.02
Silver	0.5

Solid wastes that yielded results above the proposed limitations, would require a manifest system, and disposal must be made to an approved facility. While these facilities are not yet determined or generally available at present, it is possible that they would include some combination of fixation, landfill lining, and leachate collecting and treatment.

So obvious were the consequences of these added burdens that discussions ensued between the EPA and the AES, with a view to reconciling the behavior of electroplating waste sludges under the EPA extractions procedure, with their behavior under field conditions.

The proposal for a co-operative agreement evolved during 1978 and the final draft was presented at the second EPA/AES Conference in February 1979. Approval of the funding of 95% of the program by EPA came in March 1979, and the Task Force appointed by the board of directors of AES began its work with the author as technical director.

The Task Force members were Doug Thomas, chairman, Fred Steward, Irving Ireland, Richard Crain, and George O'Connor.

Howard Schumacher, the executive director of AES was also appointed program co-ordinator, and Centec Corporation of 11800 Sunrise Valley Drive, Reston, Virginia was chosen as the engineering and laboratory sub-contractor.

The method chosen by the Task Force called for the selection of twelve sludge sources that represented the spectrum of the metal finishing industry. These were to be subjected to a series of tests.

Phase I was designed to:

- Characterize chemically and physically the solid and liquid portions of the sludges.
- Determine the effect of pH on results of the EPA extraction procedure (EP).
- Determine the effect of interstitial water, (i.e. water in the sludge) on the EP results.
- Determine the effect of sludge aging on EP results.

Phase II was designed to:

- Simulate more closely a segregated landfill containing hydroxide sludges, where there would not be severe agitation or exposure to low pH using a dynamic laboratory procedure.

Phase III:

- was a field test, where soil samples were taken below a sludge bed that had been in use for ten-twelve years at the site of one of the plants from which current sludge samples were taken. (Plant #11).

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TABLE II
PLANT DESCRIPTION

Plant	*% Solids*	*Primary Plating Process*
1A	11	Segregated Zn
2A	6	Segregated Cd
3A	3	Zinc Plating and Chromating
4A	7	Cu-Ni-Cr on Zn
5A	17	Al Anodizing
6A	34	Ni-Cr on Steel
7A	15	Multi-process Job Shop
8A	29	Electroless Cu on Plastic, Acid Cu, Ni, Cr
9A	39	Multi-process with Barrel or Vibratory Finishing
10A	24	Printed Circuits
11A	19	Ni-Cr on Steel
12A	23	Cd-Ni-Cu on Brass and Steel

Phase I, description of the experiments, results, conclusions, and recommendations are contained in the Interim Phase I Report, which was submitted in September 1979.

The complete report, under the title "Interim Phase I Report, Electroplating Wastewater Sludge Characterization" is available at no cost from John Lehman, EPA, Office of Solid Waste (WH-565), Washington, D.C. 20460. A synopsis of this paper was published in Plating and Surface Finishing.

In the interest of time, I will touch on the highlights of that report and its conclusions.

Table II describes the plants sampled and the toxic materials, as defined by the proposed RCRA regulations that were present in the sludges as weight percentage of the dry solids.

Time and resources did not permit in-depth engineering studies of the plants being sampled, but with one exception, sufficient data was obtained to describe the nature of the treatment system and the volumes involved.

Figure 1 is a schematic of the extraction procedure.

The experiments conducted included:

- Effect of pH on extraction.
- Effect of volume of extraction water.
- Reproducibility.
- Effect of temperature.

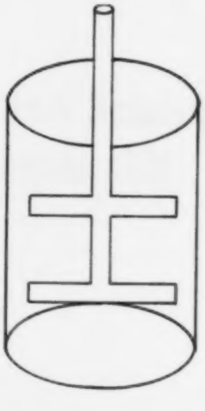

Figure I. Extraction Apparatus

- Comparison with ASTM extraction procedure.
- Effect of sludge aging.
- Total metal content.
- Anion content.
- X-ray diffraction.
- Filtrate analysis and washing.
- Filtration versus centrifuging.

In Table III, the results of the execution of the extraction procedure at a maintained pH of 5, as proposed by the EPA, and at four other pH's is shown.

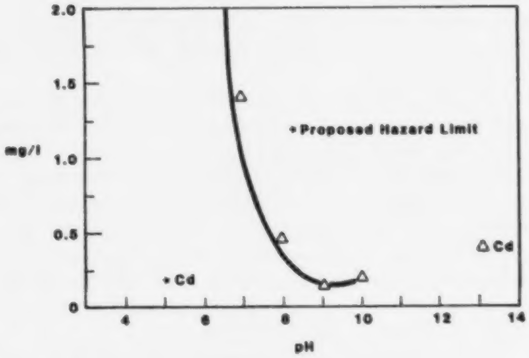

Figure II. Changes in Cadmium Concentration with pH

TABLE III
EFFECT OF PH

mg/l

Proposed Hazard Limit Metal		*0.5 Cr*	*0.1 Cd*	*0.5 Pb*	*0.5 As*	*0.02 Hg*	*0.5 Ag*
1A (11% Solids)	pH 5	1.22	0.23	0.041	0.073		<0.01
2A (6% Solids)	pH 5	1.89	126	<0.001	0.005		<0.01
3A (3% Solids)	pH 5	85.0	6.00	0.009			
4A (7% Solids)	pH 5	21.8		0.038			.02
5A (17% Solids)	pH 5	<0.01		<0.001			<0.01
6A (34% Solids)	pH 5	25.4	<0.01	.001			
7A (15% Solids)	pH 5	0.24	2.16	.003			
8A (29% Solids)	pH 5	400		0.032	0.0450	.02	
9A (36% Solids)	pH 5	0.32	0.03	.010			
10A (24% Solids)	pH 5	0.12		0.88			
11A (19% Solids)	pH 5	4.22	<0.01	0.004	0.035		
12A (23% Solids)	pH 5	4.85	263	0.031	<0.001		

Blanks, Ba, and Se were at or below detection limits.

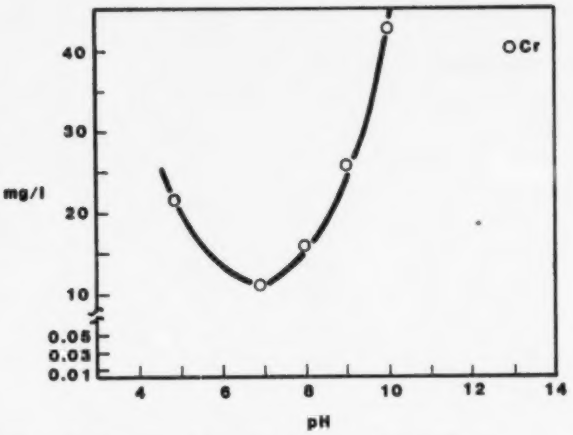

Figure III. Changes in Chromium Concentration with pH

Figures II and III show the results in graph form for typical plants with significant cadmium and chromium content.

Table IV shows the effect of aging on the EP at three months, compared with the original extraction.

The conclusions that were reached concerning Phase I were:

- EP is sensitive to pH.
- EP exaggerates the leachability of the sludge since it includes the effect of metal levels in interstitial (i.e. associated) water.
- Aging greatly decreases leachability.

TABLE IV
EFFECT OF AGING SLUDGE

EP Results mg/l
Plant 7A

		Cd	*Pb*	*Cr*
pH 5	Fresh	2.16	0.003	0.24
	Aged (3 months)	0.30	0.002	<0.05
pH 7	Fresh	0.04	0.005	0.50
	Aged (3 months)	0.01	0.001	0.15

The interstitial water is simply the supernatant and entrapped water mixed with the sludge. Its concentrations of metallic ions will be essentially the same as the plant's effluent as discharged to a water body or a municipal sewer. It is possible that a plant could be meeting an effluent discharge regulation, but would be beyond the proposed hazard limit for sludges, because of the metal content of the interstitial water alone. This point is further developed in the interim report, and I would recommend it to your attention.

Surprisingly, and in spite of the presence of some interstitial water, Plants #5 and #9 passed the very aggressive EP test.

When the distorting effect of the interstitial water is removed, the sludge then behaves in the extraction as one would expect from the laws of chemistry.

Using the results of Phase I as a guide, we were able to enter Phase II work, knowing much of the nature of the sludges with which we were dealing.

Phase II was the dyanamic testing designed to simulate segregated landfill conditions.

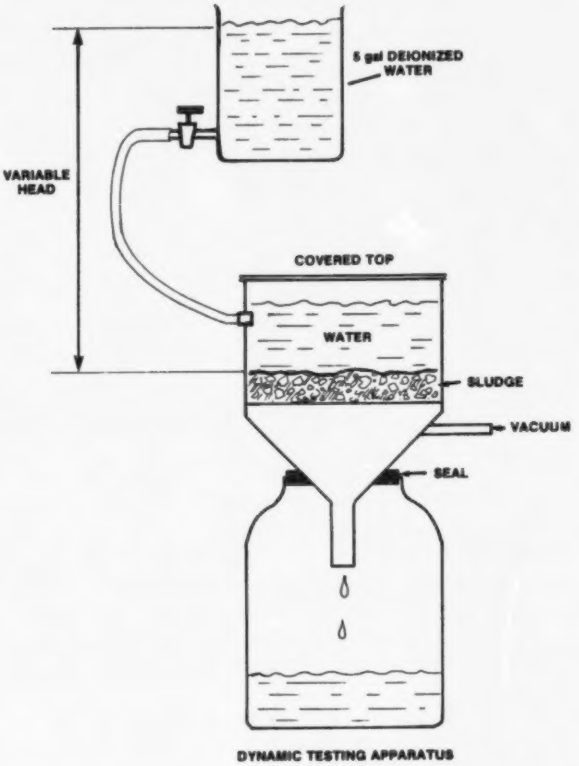

Figure IV

A reduced number of plant sludges was used for this Phase, in order to maximize the number of experiments. Plants 4, 5, 6, 8, 11, and 12 were chosen as being widely representative of those with hazardous materials, as defined by RCRA.

The complete description of the procedure will appear in the final report, which will be available this summer. However, the schematic drawing in Figure IV encompasses some pertinent data.

Samples are poured into weighed Buchner funnels seated with filter paper. D.I. water is fed from a container above the filter. A vacuum is applied to remove the interstitial waters and these are then added back to the top of the sample cake, so that it can be leached through at a more normal rate.

The leachates were analyzed on days 1, 2, 3, 5, 7, and every seventh day thereafter for the metals expected to be most predominant.

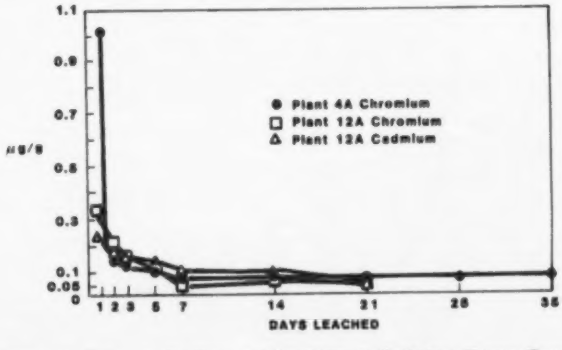

Figure V. Dynamic Testing of Chromium & Cadmium Versus Days Leached.

TABLE V
PHASE II DYNAMIC LEACHING

Days Leached
Chromium mg/l

Plant Sample Code	*EP Test Results*	*1*	*2*	*3*	*5*	*7*	*14*	*21*
4A	21.8	1.01	0.14	0.12	0.12	0.08	0.08	0.08
5A	<.01	<0.05	<0.05	0.06	0.06	0.07	0.05	<0.05
6A	184.0	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8A	400.0	*	*	*	*	*	*	*
11A	4.2	<0.05	0.05	*	*	*	*	*
12A	4.6	0.34	0.21	0.15	0.12	<0.05	0.07	0.05
				Cadmium mg/l				
12A	268	0.24	0.18	0.16	0.12	0.11	0.09	0.09

* = <0.05

The results are shown in Table V.

Figures V and VI show graphically and rather dramatically how quickly the interstitial water is flushed through, and how little material is leached thereafter.

The flow rates involved were approximately equal to one half inch of rain per day for the entire thirty-five days of the test.

It will be noted that these leaching results are approximately the same as the results obtained from the extraction made in Phase I at a pH of 7.

Although nickel is not on the list of hazardous metals as defined by RCRA, we have included it to show that it behaves in a similar manner.

The conclusions that may be drawn from the Phase II work are:

- Dynamic tests show drastically reduced levels of metal concentrations in the leachate, compared to the EP.
- This work confirms the indications from Phase I that interstitial water can be the major contributor to metals in leachate.

I would like to repeat that this interstitial water is essentially the same as the effluent and is a very small percentage of the total metal content of the sludge. A calculation of this percentage is in the Phase I report.

Also established is the fact that for a sludge source to apply stringent dewatering to his settled solids in order to pass an EP test would not, indeed, make a contribution toward improving the environment. The decision as to how much to dewater should be based on the pragmatic economics of shipping and handling, space limitations, etc.

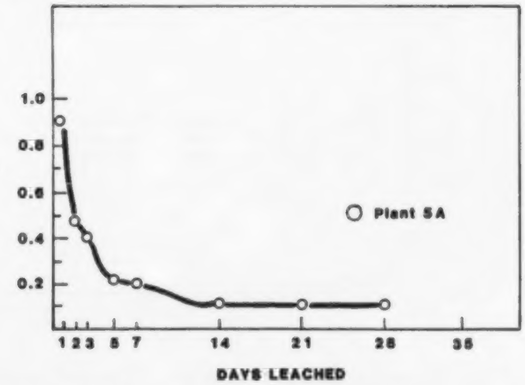

Figure VI. EPA-AES Nickel (Ni) Leachate vs Days Leached

While building the information bases in Phase I and II, we had largely exhausted our available funds. However, we did manage to have sufficient means for one field trip to the location of Plant #11.

This plant had begun to dispose of metal finishing waste treatment sludges twelve years ago in a pond created by excavation on their property. This pond became dormant six years ago and a new pond was developed some miles away that was dug to a limestone base.

In order to gain access to the soil under the pond, (there was actually two ponds), the company pumped it out just before our arrival. Samples were taken at two depths of soil below the interface and at the interface. A background sample was taken from the soil at a distance sixty feet from the pond.

During the pumping-out procedure, the suction end of the hose kept plugging with bullfrog tadpoles. Some of these hundreds of tadpoles were still alive when we arrived.

Samples were also taken from the newer limestone based pond and from a drainage ditch at a point thirty-five feet below the pond.

The results of these samplings are shown in Table VI. Each sample, except the water sample, was subjected to the EP test at a pH of 5, and some were completely digested and analyzed.

While this Phase III work was limited, (more sampling work should be done in the field) there was no result which disproved the outcome of Phases I and II, but the evidence was, rather, to the contrary. There appears to be no harmful effect on the environment when metal hydroxide sludges are disposed of in a segregated landfill.

The landfill need not be elaborately prepared, such as having lining or limestone base, and without the necessity of paying for expensive fixation treatment. This information, in turn, will permit more flexibility in the location of these landfill sites, which could also receive other sludges such as fly ash, without disturbing the plating waste sludges.

Some unfinished work, however, still remains. There is always the possibility that a malfunction of a waste treatment system may produce a sludge that would not be compatible with other sludges in a segregated landfill. It

TABLE VI
PHASE III — PLANT SITE II

New Land Fill
mg/l

Plant Sample Code	*Ag*	*As*	*Cr*
Leachate	0.01	0.004	<0.05
Surface Sludge	0.02	0.006	3.58
Subsurface Sludge	0.01	0.005	4.37
Older Subsurface Sludge	<0.01	0.002	3.35

Old Land Fill
mg/l

11" Below Sludge	0.03	0.022	<0.05
17" Below Sludge	0.02	0.011	<0.05
Sludge	0.19	0.002	0.09
Background Soil	<0.01	0.004	<0.05

(Samples were also analyzed for Ba, Cd, Pb and Se. All were below detection limits.)

is important that the sludge generator knows this before he ships that particular sludge, and for the landfill operator to know that he is receiving a "safe" sludge.

To help minimize this potential problem and to simplify test procedures, future work should include:

- Development of a quick test which would separate the effects of interstitial water from sludge leachability, and would confirm the sludge's suitability for disposal in a segregated landfill.
- Obtaining data which would provide guidance to the plater which will ensure him that his sludge will be suitable for disposal in a segregated landfill.

Much of the success of the project has resulted from the very high level of technical direction received from the Task Force and the very professional performance of Centec Corporation and its personnel.

The Task Force that volunteered its time, put more of it into this project than originally was anticipated. It always responded to the requests of the chairman, Doug Thomas, Howard Schumacher, and myself.

The co-operation of the Metals and Inorganic Chemicals Branch of EPA's Industrial Environmental Research Laboratory in Cincinnati, and George Thompson, and Fred Craig in particular were vital to the completion of this work.

Solids Removal and Concentration

Richard W. Crain*

Over the next several years it can be expected that the matter of sludge disposal will be somewhat unsettled until a national understanding is reached. That agreement could be as simple as mutual endorsement of one region's existing regulations or as complicated as adoption of "numbers" by the federal authorities. The latter with the tedious and expensive promulgation, discussion, possible litigation, and subsequent adoption phases to follow, as we've seen in the electroplating pretreatment (heavy metal) regulations.

Whatever the result, most legal authorities agree that if one set of regulations causes you to remove heavy metal sludges; other authorities must provide or endorse a place to put them.

Making the metallic hydroxides and other sludges resulting from metal finishing "PRESENTABLE" to the receiving authority or a private disposal site is the subject of this paper.

Properly neutralized and conditioned, thickened and/or dewatered sludge has been shown (1) to be relatively inert. Surprising to some, the technology for accomplishing this has been well known for over 25 years. (2-4)

Therefore, we will examine in detail the current state of the art of concentrating sludges to enable them to be handled and transported as inexpensively as possible and disposed of at approved sites.

Sludge concentration is usually known as thickening and discussed in those terms up to the 15%/wt. level. Beyond 15% we refer to a dewatered sludge (5).

COAGULATION AND FLOCCULATION

Before investigating the actual mechanical methods used to dewater this type sludge, we will first discuss the various aids to coagulation and flocculation which hasten mechanical separation.

Coagulation is the conversion by a simple electrolyte of colloidal and dispersed particles into a small visible floc. Inorganic coagulatants are simple electrolytes which are water soluble, low molecular weight inorganic acids, bases, or salts of iron, aluminum and calcium. Examples being ferrous sulfate, alum, or lime.

Flocculation is further agglomerated by a polyelectrolyte of the small slowly settling floc formed during coagulation into a large, rapidly settling floc. Organic flocculents are water soluble, high molecular weight polymers. These can be either anionic or cationic in nature and should be added in small amounts (such as 0.2-1 mg/l). However, polymeric flocculent aids are best used when tested at the job site by a technical service representative of one of the many supply companies.

It is extremely important in coagulation, flocculation, settling, and dewatering that the floc be properly formed and, once formed, treated "tenderly".

When heavy metal bearing effluents have been chemically treated to render them less or non-toxic, they must ultimately have a final pH adjustment prior to final liquid/solids separation. As sensed by automatic pH control, the optimum pH for the great bulk of mixed metal finishing wastes is 8.3. (5)

Lime and/or caustic should be added into the vortex of the mixer of a tank type final neutralization. Mixing should be slow so as to promote coagulation created by this inorganic acid. Organic (polymeric) flocculation should be introduced at the exit of the final neutralization basin. Such introduction should be made in a quiescent zone as a part of, or prior to, a clarifier.

Whatever method is ultimately selected to dewater this type of sludge, certainly lab tests, if not actual on site pilot systems should be used to determine cycle lengths, cake dryness, and ease of handling.

EQUIPMENT AND PROCESSES (5)

Numerous processes and equipment types are available for sludge thickening and dewatering. Criteria for selecting one or more techniques depend on the characteristics and the amount of sludge to be processed, capital and operating funds available, size and type of treatment plant, cognizant regulatory requirements, and the final disposition.

Terms used in describing sludge handling requirements and equipment are defined in Table I. The general types

TABLE I
TERMS—DESCRIBING SLUDGE HANDLING EQUIPMENT

- **Solids Loading—Percent Solids in Stream**
- **Cake Conc.—% Solids by Weight in the Thickened or Dewatered Sludge**
- **Capacity—Flow Rate of Wastewater or Volume/Cycle - Time of Batch Devices**
- **Particle Size—Diameter of Particles**
- **Solids Recovery or Solids Retention—% of Solids in the Input Stream Removed in the Thickening Process.**
- **Yield—Output of Filter in Pounds of Solids per Square Foot of Filter per Hour**

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TABLE II

CLASSES OF EQUIPMENT AVAILABLE FOR THICKENING AND DEWATERING

TYPE	FEED RATE (GPM)	SOLIDS LOADING (% SOLIDS)	PARTICLE SIZE (MICRONS)	SOLIDS RETENT. (% SOLIDS)	OUTPUT CAKE CONC. RANGE (% SOLIDS)	CAP. INVEST. ($1000)	APPLICATIONS	
							PRIMARY	SECONDARY
STIRRED GRAVITY	10-3000	—	—	95-98	5-10	14-140	PRIMARY AND SECONDARY, METALLIC, CHEMICAL	INDUSTRIAL
AIR FLOTATION	10-10,000	—	—	92-98	5-10	28-560	WASTE-ACTIVATED, LIME, FLOCCULATED ALUM	PRIMARY, SECONDARY, INDUSTRIAL, TRICKLING FILTER
CENTRIFUGES								
DISC	25-300	0.2-1	$1-10^5$	90-95	5-10	28-196	WASTE-ACTIVATED	
SCROLL	5-300	0.5-15	$1-10^6$	60-95	20-45	28-280	RAW OR DIGESTED PRIMARY OR SECONDARY, ALUM, LIME	INDUSTRIAL
BASKET	10-60	1-10	$1-10^6$	90-95	5-25	28-168	WASTE-ACTIVATED, LIME, ALUM	HYDROXIDE
FILTERS								
VACUUM DRUM	0-250	8-10	$5-10^6$	50-99	20-40	7-42	DIGESTED PRIMARY OR SECONDARY	CHEMICALLY PRECIPITATED
VACUUM BELT	1-50	5-10	$1-10^2$	75-90	15-25	21-105	INDUSTRIAL	CLARIFIER OVERFLOWS
PRESSURE	10-250	2-5	$1-10^2$	95-99	20-50	7-700	ALUM, WASTE-ACTIVATED, HYDROXIDE	MUNICIPAL, INDUSTRIAL, CHEMICAL
BELT	5-200	4-6	$10-10^2$	95-99	20-35	14-168	SECONDARY BIOLOGICAL	PETROCHEMICAL, INDUSTRIAL
DUAL CELL GRAVITY	10-500	0.5-5	—	90-98	10-20	—	PRIMARY AND SECONDARY	METAL HYDROXIDE

of equipment available for thickening and dewatering are shown in Table II, with indications of performance which can be achieved. In general, each class of equipment and device will have advantages and disadvantages for a specific application. Your application and the equipment available can often be matched by answering the typical questions which should be asked as shown in Table III.

The method or device used to achieve your desired result may be one of the following (7):

A. Lagooning/Drying Beds

Lagooning as a method is no longer widely accepted, although many lagoons still exist. Usually, a 4-17 day holding capacity is required to achieve proper settling. Such space allocations in populated areas are becoming prohibitive.

Further, two basins, 3-5 feet deep, are required so that one can dry while the other is in use. Depending on the evaporation rate in that region, this could take 6 months to 2 years. The ground water can be contaminated by insufficient lagoon lining (natural or artificial).

At the end of the drying period, they usually only achieve a 4-10%/wt. solids. Further dewatering can be achieved by spreading this sludge over a coarse bed of sand, coal, or gravel. 25-40%/wt. solids can be achieved in this way under optimum climatic conditions.

B. Clarifiers

The discussion of clarifiers (8-12) will be divided into four categories, namely; gravity, stirred gravity, dissolved air flotation (DAF), and rapid settlers.

Figure #1 illustrates a conventional gravity settler. Typically these units can thicken from 2 to 10%/wt. With these, a sludge blanket is formed by proper sizing and flow distribution which is extremely important. So, too, is the sludge withdrawal rate, so as not to upset the system, creating high TSS discharges. Such units are relatively inexpensive but do occupy considerable floor space. Figure #2 points to design parameters affecting clarifier design.

TABLE III

QUESTIONS TYPICALLY ASKED IN MATCHING APPLICATIONS REQUIREMENTS WITH EQUIPMENT PARAMETERS

- **Operational Variables Affect Equipment Performance**
- **Throughput, and Feed Rate vs. Solids Loading**
- **Pretreatment of the Sludge Needed to Reduce Moisture so that Input Solids Loading is Acceptable**
- **Effectiveness - Relationship Between Solids Recovery and % Solids in Output Cake**
- **Cost of Purchase, Including Engineering and Installation**
- **Cost of Operation, Including Chemicals, Labor, Maintenance, and Replacement of Expendable Parts**

The next figure (#3) illustrates a conventional stirred clarifier. These are open cylindrical tanks with the influent feed normally at the center and with some means for distributing the sludge radially. The solids are drawn

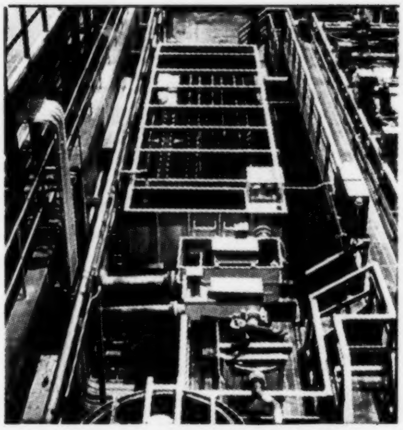

Figure 1—Conventional Gravity Setter.

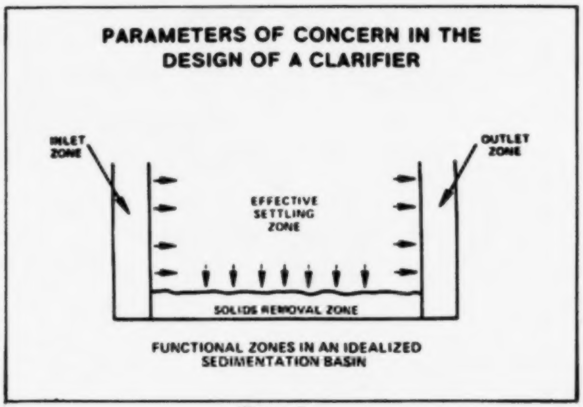
PARAMETERS OF CONCERN IN THE DESIGN OF A CLARIFIER
INLET ZONE
OUTLET ZONE
EFFECTIVE SETTLING ZONE
SOLIDS REMOVAL ZONE
FUNCTIONAL ZONES IN AN IDEALIZED SEDIMENTATION BASIN

Figure 2.

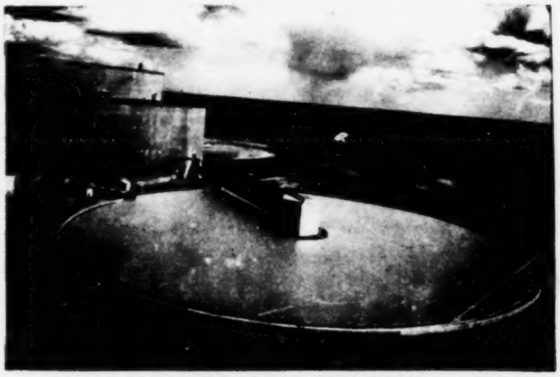

Figure 3—Conventional Stirred Clarifier

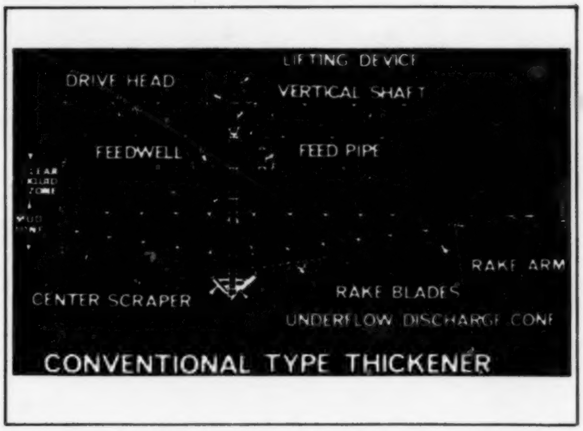
LIFTING DEVICE
DRIVE HEAD
VERTICAL SHAFT
FEEDWELL
FEED PIPE
RAKE ARM
CENTER SCRAPER
RAKE BLADES
UNDERFLOW DISCHARGE CONE
CONVENTIONAL TYPE THICKENER

Figure 4—Schematic Diagram of Solids Contact Clarifiers.

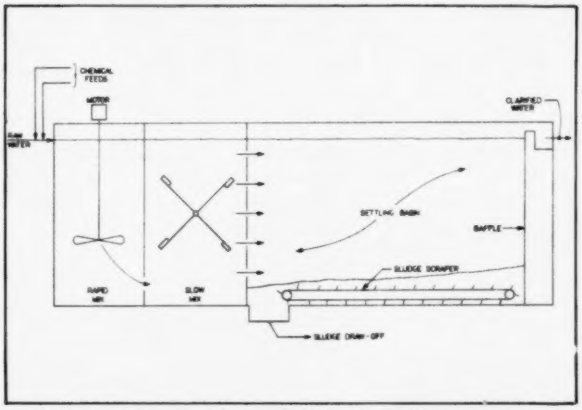
CHEMICAL FEEDS
MOTOR
RAW WATER
CLARIFIED WATER
SETTLING BASIN
BAFFLE
SLUDGE SCRAPER
RAPID MIX
SLOW MIX
SLUDGE DRAW-OFF

Figure 5—Schematic Diagram of Horizontal Clarifying Equipment.

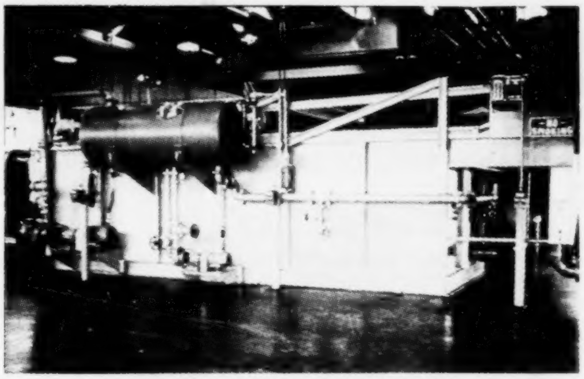

Figure 6—Dissolved Air Flotation Unit

off at the center (figure #4) and with proper conditioning can reach 10% levels. The effluent could still contain up to 50 ppm TSS.

Horizontal clarifiers are also common. Figure #5 illustrates a typical unit. Note should be taken of the several mechanical methods used to slow agitation and promote flocculent growth. Any significant agitation or introduction of air bubbles will destroy the sludge settlement.

Another type of unit (DAF), in fact, takes advantage of this phenomenon. Dissolved air flotation units (figure #6) are the reverse of the clarifiers described thus far. They are generally open tanks into which a gas or air is bubbled. The sludge particles become attached to the fine bubbles and float to the surface where they are skimmed off. The underflow is the "clear" effluent. Factors affecting the effectiveness of these units are particle size, specific gravity, air to solids ratio, and the removal (skim) mechanism.

Rapid settlers may be tube type, plate, and other laminar (lamella) settlers. These units are said (10) to require only 1/4th to 1/10th the floor space required for conventional gravity and stirred gravity types. They use the design of angular tubes or plates which have extremely high surface areas and only 3/4 to 2" drop of solids in angular (usually 45°) tubes or parallel plates (figures #7 and #8). The units produce a sludge of up to 10% and an overflow of 10-30 ppm TSS. They are often installed inside and are easily maintained. The principal disadvantage is said to be a blocking of the channels or tubes, if there is an improper sludge draw-off.

Laminar flow packs can even be installed in EXISTING conventional clarifiers to enhance the effectiveness (figure #9) or increase their capacity without enlarging them.

C. Centrifuges (5, 6)

These units are normally very compact. They are the first units to be discussed which DEWATER rather than thicken according to our earlier definition. They are highly influenced by the influent rate and percent solids in the feed. They can typically dewater to 15%. The centrate almost always must be recycled as it contains 500-1,000 ppm TSS. Centrifuges have a high power consumption and some history of maintenance problems due to their high rotation rate. Slower speed units are being developed and becoming popular. Figure #10 illustrate a bowl centrifuge.

D. Vacuum Filters (5, 6, 12)

Rotary drum vacuum filters have been used for many years in all facets of sludge dewatering. However, unless they are precoated with a filteraid material, they normally require that the influent sludge be thickened (by one of the methods described in "B" above.) Figure #11 illustrates a rotary vacuum filter. The submergence of the drums is normally in the 30% range. Therefore, the efficiency of these units is low, but the fact that they are continuous is a very favorable offset. These units are also relatively energy intensive and are said to potentially have problems associated with maintaining a vacuum.

The rotary vacs dewater to 25-35% with the filtrate in the 100-700 ppm range for those who do not use precoat.

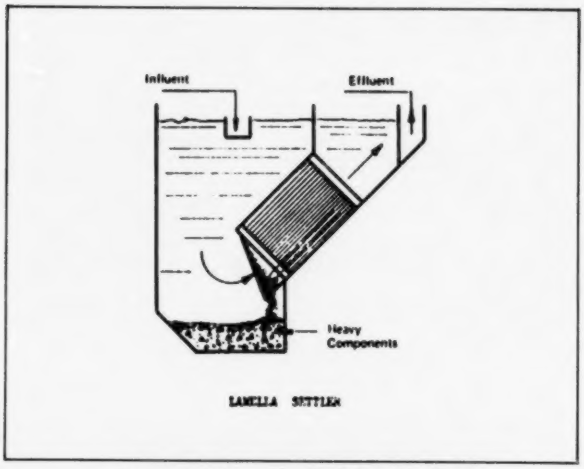

Figure 7—Schematic - Tilted Plate Clarifier.

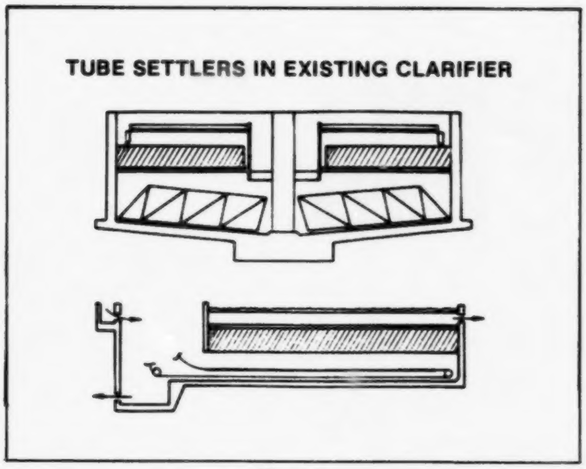

Figure 9.

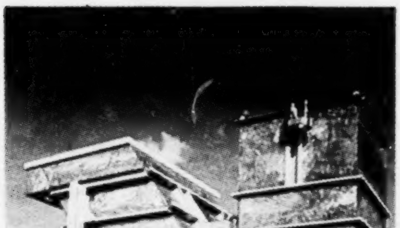

Figure 8—Production Unit - Tilted Plate Clarifier.

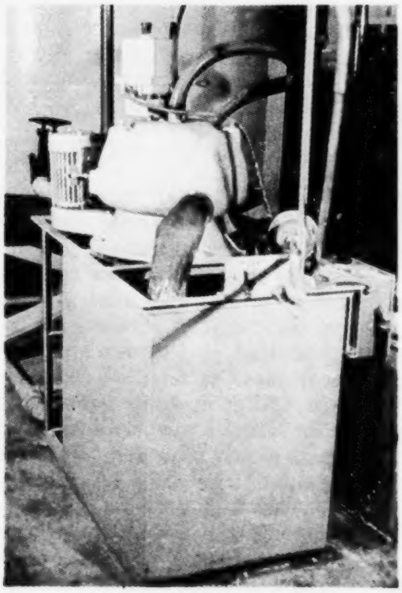

Figure 10—A Bowl Centrifuge.

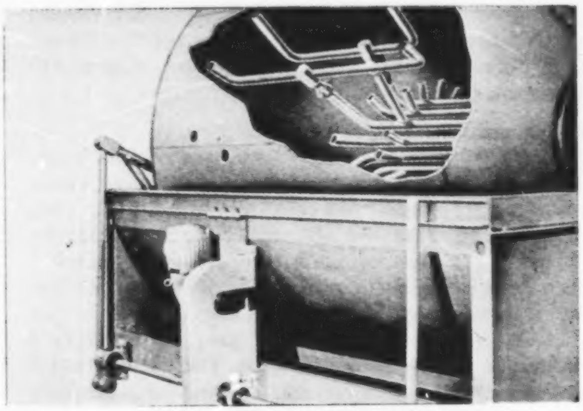

Figure 11—Rotary Vacuum Unit.

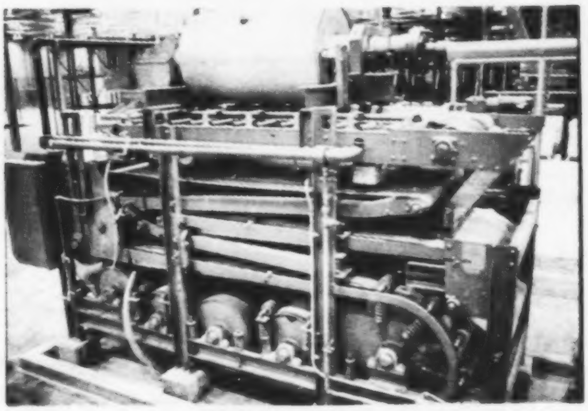

Figure 12—Belt Filter.

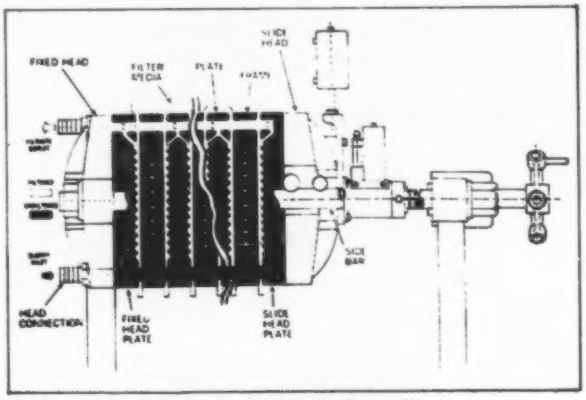

Figure 13—Plate/Frame Press Filter.

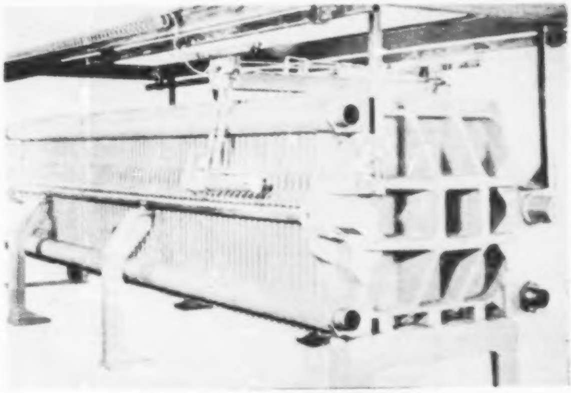

Figure 14—Typical Plate/Frame Filter.

E. Belt Filters (6, 12)

These units (figure #12) distribute gravity flow and through a series of belts allow for the drain off of the liquid phase. A second stage employs pressure rollers. The units are continuous and relatively inexpensive. They do normally require conditioning chemicals or prior thickening in order to produce 15-20%/wt. solids. The belt is washed for reuse on a continuous basis to inhibit blinding. The filtrate contains 500-2,000 ppm TSS. Design rates are 2-8 GPM/sq. ft.

F. Filter Presses (5, 6, 8, 13)

Filter presses have been widely used in the chemical process industries since the 1920's. Although there are many configuration variations, a plate/frame press consists of a number of vertical plates which are held rigidly in a form to ensure alignment. The trays are recessed so that when pressed between the fixed and moving ends of the head, they form a hollow chamber (figure #13). The inside of each hollow chamber is lined with a filter cloth. Sludge is pumped through holes in each chamber. The drainage member behind each cloth allows for passage of a clean filtrate and deposition of the sludge on the cloth. Dewatering takes place as the influent sludge reaches high pressure (100-200 PSIG). Cake is ½ to 1" thick and 40-50%/wt. solids can be expected. The filtrate clarity is 0-10 ppm TSS depending on whether the unit is first precoated or not. Figures #14 illustrates a typical P/F press.

Another press variation is the conventional pressure leaf type filter unit, with compressive diaphragms or membranes. These units operate at much lower pressures (approximately 50-70 PSIG).

Both conventional plate and frame and the compressive diaphragms have received wide acceptance as the devices offering the driest possible cake. Flow rates are 1/10th to 1/20th GPM/ft^2.

G. Pressure Leaf Precoated Filters (3, 5, 6)

These pressure leaf units operate at much lower (up to 40 PSIG) pressures then plate and frame presses (up to 200 PSIG). Normally, they use a precoat on a conventional leaf. Rates are typically 1/4th to 1/10th GPM/ft^2. The cakes (figure #15) are 35-40%/wt. and the filtrate the best of any dewatering device (0-5 ppm). Relatively large units are required for the DIRECT filtration of metallic hydroxides (example . . . 1,000 ft.^{2} for 100 GPM). However, no other devices are needed. There is no requirement for thickening ahead or polishing behind these units.

Other pressure leaf units (figure #16) will accept prethickened sludge at rates of 1/20th GPM/ft.^{2} or direct filtration at 1/4th GPM/ft^2 producing a 20% dry solids in either case on an automatic basis.

H. Fixants and Incineration

These two methods of making dewatered sludge "PRESENTABLE" share one thing in common. The

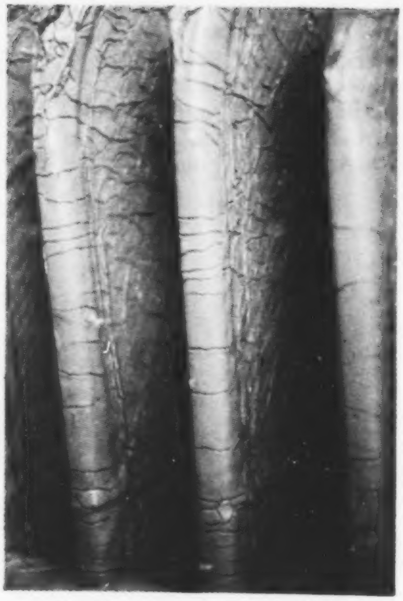

Figure 15—Pressure Leaf Filter Cake.

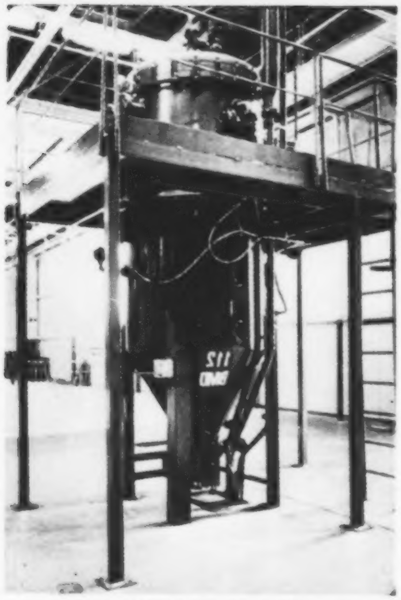

Figure 16—Pressure Leaf Filter.

dryer the dewatered cake fed to the fixant or incinerator, the more economical the method.

Chemical fixant processes have been evident for about 10 years (13, 14). Most common processes incorporate the addition of a silicate compound in order to produce a concrete like product. The feed to these processes could be anywhere from 2% (clarifier underflow) to 40% (filter press cake).

The economics of these methods have yet to be clarified for metal finishing wastes. However, more and more interest has been shown by the industry and general public.

Incinerators too have been used (though not widely) for over 10 years as a method of making sludge "PRESENTABLE." Multiple hearth and rotary hearth incinerators are in common use. A study (15) shows the most economical sludge to be handled is that from a pressure leaf or plate and frame press. However, an evaluation of these, filters, belt presses, centrifuge, and vacuum filters indicate they are also said to be the most expensive method of dewatering.

We have painted the subject of making metallic hydroxides presentable with a rather "broad brush." From drying beds on the low end, to incinerated or chemically "fixed" sludge (which was first thickened and later dewatered ahead of it) on the high end.

The question which ultimately must be answered is . . . in what condition will *MY* sludge be accepted and how can I get it to that point at the least overall cost? The methods or combinations described here can achieve any requirement which you will be given. Which method you use over all, and over the next few years can *ONLY* be determined by your regulatory requirements; then examined in detail by your supplier and/or consultant.

ACKNOWLEDGMENTS

In the preparation of this paper, 15 companies well known in the industry were asked to contribute information and/or slides.

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5. Haviland Products, Inc., Grand Rapids, MI.
6. D. R. Sperry, Batavia, IL
7. Industrial Filter & Pump Mfg. Co., Cicero, IL

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Making Hazardous Wastes Nonhazardous

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INTRODUCTION

Once a waste is designated or declared to be "hazardous" under the Resource Conservation and Recovery Act (RCRA) it becomes subject to a myriad of rules and regulations promulgated by the U. S. Environmental Protection Agency (EPA). RCRA regulations require strict control of hazardous wastes from "cradle-to-grave;" i.e., from generation, through transportation, storage, treatment, and disposal. There is little doubt that these regulations will change the way industry does business. The cost of disposal will go up, the financial impacts will be significant, the technical requirements will increase, and the paper work will grow. Under RCRA you will be required to do the following:

- Provide notification if you produce "hazardous" wastes
- Provide proper containerization for "hazardous" wastes
- Maintain complete records of waste generation, handling and disposal
- Obtain permits for treatment, storage, transportation, and disposal.

To make matters worse, the design and operating requirements for "hazardous" waste disposal will serve to diminish the already limited off-site capacity. Would it not be great to convert the hazardous waste into a nonhazardous material?

THE CONCEPT

EPA has chosen to use an elutriate test to determine whether toxic components can be leached from the waste. The analysis of the extract from an operationally defined procedure determines whether the waste is hazardous by the toxicity characteristic. Separate testing must be done for ignitability, corrosivity, and reactivity. Now let us suppose that the waste is toxic according to the test and suppose that the waste were incorporated either chemically or physically in an inert and monolithic matrix. EPA's protocol as proposed in the December 18, 1978, *Federal Register* calls for the use of the structural integrity procedure on solidified wastes.

The basis for the use of this procedure developed from EPA's concern that if these monolithic solids do not physically break down during disposal, it would be inappropriate to grind the waste into smaller particles than is necessary for elutriate testing. Certainly the leaching characteristics for a divided waste will be quite different from that of the waste in monolithic form. The structural integrity procedure was designed to be a moderately severe approximation of the disintegration which might be expected to occur if a solidified waste was used as fill or construction material. Under these conditions crushing might occur from the passage of heavy equipment over the waste. After conducting this test on the solidified waste, the intact solid, with its greatly reduced surface area, is extracted. If the waste passes the toxicity test requirements and does not have the other characteristics listed above, it can be declared nonhazardous. A less stringent set of regulations under RCRA Subtitle D may be used for the solidified waste handling. However, if the waste is "hazardous" prior to solidification, a permit to treat hazardous waste will probably be required.

SOLIDIFICATION PROCESSES

A wide variety of commercial solidification processes are available. Many of the vendors have had specific experience with wastes from this industry. A number of references written or edited by the author on these processes may be found at the end of this paper.

The waste generator may choose to develop and use a generic solidification procedure. This can be done by selecting the proper solidification agent and following the conceptual flow outlined below. However, the industry should realize that the process may require substantial engineering and development costs to initiate. Many of the vendors are already prepared to adapt their processes to your wastes.

Recently a number of processes have been developed specifically to handle organic-contaminated inorganic wastes and organic wastes with metals contamination. These two cases had posed problems in the past thereby effectively limiting solidification to inorganic wastes. Solidification has also been used in conjunction with incineration for organic wastes. This has been done by solidifying the waste for ease of handling, incinerating the waste for volume reduction, and resolidifying the ash. Inorganic solidification processes have been used to solidify the toxic ash derived from conventional incineration of organic wastes.

There are typically five steps involved in solidification. They are: waste collection, waste pretreatment, solidification agent addition, mixing/packaging, and disposal. Each step is briefly discussed below.

Waste Collection. A plant may wish to segregate to a greater extent these wastes which it wishes to solidify. This may involve some degree of retrofiting. Of those wastes targeted for solidification, it is important to determine how the blending of the wastes will affect the processes chosen for pretreatment and solidification. If the waste is "hazardous" at the collection point and must be stored for more than 90 days, you will require a permit for this activity. A manifest will be required if the waste is

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transported off-site for solidification. In-line solidification would be required to avoid these requirements.

Waste Pretreatment. Some wastes can be solidified directly, while others may require pretreatment. Physical pretreatment processes required by some processes include decanting, centrifugation, dewatering, evaporation, or calcination. To reduce leaching from the solidified waste, cyanide destruction, neutralization or chromium reduction may also be required prior to solidification. At a regional treatment facility these processes might be accomplished with another waste thus reducing the cost. The generator who requires chemical treatment prior to solidification might search for a process which does not have this requirement. If the treatment alone detoxifies the waste, there may be no need to solidify the waste except for handling.

Solidification Agent Addition. There are five basic types of solidification as it may be applied to this industry. These types include the following:

- Cement-based
- Lime-based
- Thermoplastic-based
- Organic Polymers-based
- Encapsulation and Coatings

Each of the processes in these categories has its own requirements for adding the agent. The amount of additive will probably be dictated on the lower end by the specifications required to pass the structural integrity procedure. Other specifications may be required depending upon the end use of the material.

Mixing/Packaging Systems. Solidification is often conducted either in a container or by in-line mixing with containerized or uncontained discharge. In-container mixing of the waste and solidification agent can be accomplished with roller mixers, tumbler mixers or paddlemixers. In-line mixing is accomplished either by dynamic or batch mixing. If containers are used, they must still be inspected, monitored and labeled. Interim storage and track leading facilities will also be required. Uncontained release is directed to the disposal facility.

Disposal. If the solidified waste has been tested and deemed to be nonhazardous the disposal site must meet RCRA Section 4004 requirements at a minimum. There may be pressure brought to bear by the states to upgrade these requirements. However, if all the solidified wastes going into a landfill are deemed nonhazardous, the landfill need not be a secure chemical landfill for hazardous wastes. There are a number of productive uses of solidified wastes which may decrease the need for strict disposal and provide an incentive to the use of solidification. Some of these demonstrated uses are as follows: land reclamation, road bed aggregate, artificial reefs, parking lot pavement, impermeable liners, and landfill capping material.

CONCEPT INSURANCE

Questions are often asked as to whether the solidified waste will hold up over time. To insure that this will happen, physical, leach and accelerated environmental testing may be required on representative samples using established protocols. EPA has sponsored a number of studies to look at some of these questions. Unfortunately most of the solidified wastes were not designed to meet the common point of passing the structural integrity procedure. Varying amounts of additives were used by the participating vendors making comparisons between processes for a particular waste type very difficult. Furthermore, there is no great amount of concensus in the testing area. However, ASTM has recently mounted a special effort to solve this problem.

Accelerated testing is perhaps the most controversial aspect of concept insurance. Most tests which are designed to be representative of environmental conditions take too long to generate useful data. Just as aerospace construction and electrical components are tested for long-term viability with accelerated techniques, a similar approach must be adapted to the wastes. The selection of the proper test should be attempted only after the use of disposal technique is specified.

ON-SITE vs OFF-SITE SOLIDIFICATION

This is a real controversial choice confronting the generator. Off-site regional solidification offers economy of scale and potential to use other wastes for neutralization and other pretreatment. A potential problem is that the wastes will be mixed with other wastes and there is a question of potential future joint liability. The wastes must also be manifested with this option if they are hazardous. On-site solidification gives the generator more control over the processing and handling of his own wastes. It may also remove some of the manifesting requirements. Some solidification technology vendors operate exclusively in one mode or the other. Other vendors operate in either mode to suit the needs of a customer. Legal and economic factors must be carefully weighted by the waste generator before deciding which route to take.

CONCLUSIONS

Solidification has great potential as an advanced pollution control technology for the metal finishing industry. New EPA regulations should hasten the development and incorporation of solidification techniques into a much broader segment of the industry. Solidification should be considered as an option in the hazardous waste management planning that each facility must go through in order to be brought into compliance with the RCRA regulations.

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Radiochemical Studies of the Leaching Of Metal Ions from Sludge Bearing Concrete

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Walter P. Saukin and Robert J. Spinna**

INTRODUCTION

The possibility of incorporating electroplating sludge into concrete as an alternative disposal procedure to the use of segregated landfills has been examined earlier in the report of work done under Research Project 49-Phase I of the American Electroplaters' Society.[1] The ultimate rationale for this exploratory study was the fact that the ready-mix concrete industry in the United States provides a potential daily capacity for disposing of more wastewater sludge than the entire electroplating industry generates on the same daily basis at a cost which could be significantly less than that of current disposal methods.

While the chemistry of concrete is not fully understood, it is known that the hardening process is the result of the reaction of calcium silcates, calcium aluminates, and tetracalcium alumino-ferrite with water to form hydrates that resemble the natural minerals tobermorite and the hydrogarnets as well as other hydrates and calcium hydroxide. These reactions are summarized in Figure 1. The most important of these is tobermorite which, in concrete, is formed in an extremely finely divided manner with a coherent structure that is given the name gel. Thus the hardening of concrete can be seen as the process of making artificial minerals. Aluminum, iron, and some of the calcium in concrete are bound and rendered insoluble in the same manner as these metals are bound in natural rocks. It is not unreasonable that other metal ions could be mineralized in this manner. In addition, the possibility exists that the metal ions could be immobilized within the molecular sized gel pores that are formed in concrete during the hardening process. The extent to which metal ions have been mineralized in concrete, made with electroplating sludge as part of the mixing water, can be determined by analysis of the leach water. While other testing may be required to establish the exact nature of the metal binding, leaching studies will give evidence of the feasibility of the method and indirectly of its environmental acceptability.

Radiochemical techniques for conducting these studies were employed because they provide a fast, accurate, and extremely sensitive method of identifying the metal and its concentration in the leach water.

The results obtained in phase I were sufficiently encouraging, in respect to both the quality of the concrete and the binding of the metal compounds, that phase II was undertaken. This paper will consider the leaching studies that were done in both phases of the work to determine the extent to which metal ions leave sludge-bearing concrete and enter ambient immersion water. In some respects this can only be a progress report; the final results will be included in the report to be given at SUR/FIN '80 in Milwaukee this June.

EXPERIMENTAL PROCEDURES

In both phases of the work the composition of the concrete mix was the same as that used in the physical tests. It consisted of a water/cement ratio of 7.0 (gal/ft^3) and an aggregate/cement ratio of 5.5 (lb/lb). The aggregate was 35% sand, 65% coarse aggregate. This corresponds to a conventional 1:2:4 mix. In phase I, only Type I normal Portland cement produced by the Saylor Portland Cement Company was used. In phase II, both Type I (Saylor) and Type III High-Early-Strength (Atlas Portland Cement Company) were used. The compositions of these cements are shown in Table 1. Type III cement has a very large tricalcium silicate content because it is this substance that hardens rapidly and is largely responsible for the initial set and early strength of concrete. In phase I the coarse aggregate was washed natural stone; in phase II, 3/8" crushed trap rock was used.

The water component was replaced by sludge that was adjusted to a 1.5% solid component in phase I and a 2.0% solid component in phase II. The sludge was obtained from the following sources:

New England Plating Co., Inc. Worcester, Massachusetts	NEP
WHYCO Chromium Co., Inc. Thomaston, Connecticut	WHYCO
Contract Plating Co. Stratford, Connecticut	CPC

$$\underset{\text{(Tricalcium Silicate)}}{2(3CaO\cdot SiO_2)} + 6H_2O \longrightarrow \underset{\text{(Tolbermorite Gel)}}{3CaO\cdot 2SiO_2\cdot 3H_2O} + 3Ca(OH)_2$$

$$\underset{\text{(Dicalcium Silicate)}}{2(2CaO\cdot SiO_2)} + 4H_2O \longrightarrow \underset{\text{(Tobermorite Gel)}}{3CaO\cdot 2SiO_2\cdot 3H_2O} + Ca(OH)_2$$

$$\underset{\text{(Tetracalcium Aluminoferrite)}}{4CaO\cdot Al_2O_3\cdot Fe_2O_3} + 10H_2O + 2Ca(OH)_2 \longrightarrow \underset{\substack{\text{(Calcium Aluminoferrite Hydrate)}\\ \text{(Hydrogarnet)}}}{6CaO\cdot Al_2O_3\cdot Fe_2O_3\cdot 12H_2O}$$

$$\underset{\text{(Tricalcium Aluminate)}}{3CaO\cdot Al_2O_3} + 12H_2O + Ca(OH)_2 \longrightarrow \underset{\text{(Tetracalcium Aluminate Hydrate)}}{3CaO\cdot Al_2O_3\cdot Ca(OH)_2\cdot 12H_2O}$$

$$\underset{\text{(Tricalcium Aluminate)}}{3CaO\cdot Al_2O_3} + 10H_2O + \underset{\text{(Gypsum)}}{CaSO_4\cdot 2H_2O} \longrightarrow \underset{\text{(Calcium Monosulfoaluminate)}}{3CaO\cdot Al_2O_3\cdot CaSO_4\cdot 12H_2O}$$

Figure 1—Chemical Reactions in the Hardening of Concrete.

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The radioactive nuclides that were used were mixed with the appropriate quantity of sludge and allowed to equilibrate. The cement and aggregates were dry mixed. The liquid and solids were hand blended until a uniform mix was obtained, which was then mechanically agitated and placed in forms. Separate batches were prepared for each metal and cement variation. The batch size was sufficient to prepare three 2-inch by 4-inch cylinders, except in the case of the final experiment in which the EPA Toxicant Extraction Procedure[2] was followed when only a single cylinder was prepared.

The radionuclides employed for the metals tested and their relevant properties, the sludge sources, the concentration of the metals present in the sludge, and the type of cement used are summarized in Table 2.

All of the cylinders were cured under conditions of 100% humidity for 48-72 hours when Type I cement was used, and for 72 hours to a week when Type III cement was used. Following this, the concrete cylinders were separately immersed in beakers containing 400 ml of deionized water, which were kept tightly covered. Sampling of the leach water was done periodically. For the ^{45}Ca, ^{63}Ni, ^{26}Al, and ^{115m}Cd systems, four-1.0 ml aliquots were transferred successively to planchets and evaporated to dryness. The radioactivity of each planchet was measured in a windowless gas-flow proportional counter. Background and standard counts were taken before and after each days counting.

Table 1
Composition of Various Types of Cements

	I	II	III	IV	V
Tricalcium Silicate	53	47	58	26	40
Dicalcium Silicate	24	32	16	54	40
Tricalcium Aluminate	8	3	8	2	4
Tetracalcium Alumino-ferrite	8	12	8	12	9
Total	93	94	90	94	93

The leachates from the ^{65}Co, ^{51}Cr, ^{54}Mn, and ^{65}Zn systems were sampled by taking a single 4.0 ml aliquot from each. The three 4.0 ml aliquots for each system were combined in the same vial, except in the chromium-high early system, where each leachate was measured separately, because each cylinder was given a different state of integrity. A 400-channel analyzer with a 3" × 3" NaI well counter and a 1024-channel analyzer with a standard NaI well counter were used for the γ-counting. They were calibrated periodically using ^{137}Cs and ^{60}Co standards. Each sampling, which represented exactly 1% of the leach water, was replaced with the same amount of deionized water thus maintaining a constant leachate volume. It should be noted that typical cylinder had a mass of 440 g and a volume of 210 cm^3. Thus fixing the leachate volume at 400 ml made a very confined and virtually stagnant system. It was judged that this would resemble most severe natural conditions. In the final experiment, however, the EPA procedure, requiring a water mass of 16 times the mass of the solid material, was followed.

In addition the pH of the leach water in the control samples was measured each day. In the final experiment, again following EPA procedure, the pH of the leach water was maintained at 5.0 for 6 days by the addition of 0.5 M acetic acid.

Measured counting rates were converted to absolute disintegration rates by computational methods outlined in Chandra[3] and Snell[4], and by the use of reference sources. Decay scheme corrections were used where appropriate. When nuclides of short half-life were used, all disintegration rates were normalized to the day on which the samples were prepared.

RESULTS AND DISCUSSION

This section will be divided into subsections, each of which will consider one of the metals tested.

The chemical form of the metal is not determined. It is assumed that the radioactive isotope equilibrates with the

Table 2
Cement type

Radionuclides and relevant properties				Activity Incorporated (μCi)*/ cylinder	Sludge source	Metal concentration in sludge	Cement type used
	Half life	Energy(MeV)	Particle				
^{26}Al	7.2×10^5 yr	1.16$_{max}$	β^+(82.1%)	0.0015	CPC	to be determined	I
^{45}Ca	165d	0.253$_{max}$	β^+(100%)	3.3	—	~45% of cement	I
^{115m}Cd	44.6d	1.62$_{max}$	β^-(100%)	13.3	NEP	600 ppm added	I & III
^{60}Co	5.27 yr	1.173	γ	1.7	WHYCO	500 ppm added	I
		1.332	γ (99 + %)				
^{51}Cr	27.7d	0.320	γ(10%)	167	NEP	600 ppm added	I & III
		(from 51$_V$)					
^{54}Mn	312.5d	0.835	γ(100%)	1.7	WHYCO	300 ppm added	I
^{63}Ni	120 yr	0.066$_{max}$	β^-(100%)	33 phase I	NEP	270 ppm phase I	I
				13.3 phase II		510 ppm phase II	I & III
^{65}Zn	244d	1.116	γ(50.7%)	3.3 phase I	NEP	300 ppm phase I	I
		(from 65$_{Cu}$)		1.7 phase II		570 ppm phase II	I & III

* 1μCi = 2.22 × 10^6 disintegrations/min

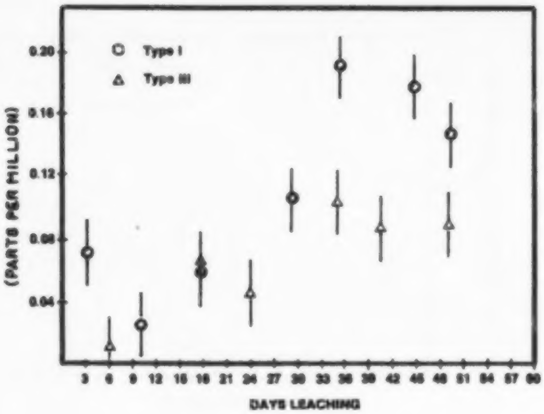

Figure 2—Concentration of Cd in leach water as a function of immersion time of sludge bearing concrete by beta counting.

naturally occurring isotopes in the sludge and adopts the same chemical states as the latter in all parts of the system.

1. *Aluminum*

The results with respect to the rate at which this metal is leaching from the concrete are inconclusive. The lower limit of detection is about 1 ppm because of the small amount of radio-activity that was incorporated. Because it is cyclotron produced, ^{26}Al is very expensive - about \$500/0.01 μCi. To obtain an increase in sensitivity of 10, about 0.05 μCi would have to be used. Hence, other methods of rapid and sensitive analysis are being investigated. Nevertheless, the measured activity of samples taken over a period of 118 days of leaching was never consistently above background. This leads us to conclude that the aluminum from aluminum bearing sludge does not leach to an extent greater than 1 ppm in this system.

2. *Cadmium*

Because none of the sludges used were known to contain cadmium, it was added to the NEP sludge as $Cd(NO_3)_2 \cdot 4H_2O$ at a concentration of 600 ppm. Cylinders were made using both Type I and Type III cement. The results obtained for this metal are shown in Figure 2. They appear to be higher than for any of the other metals, especially in the case of the Type I cement. For cylinders made with Type III cement, the leaching is generally lower.

3. *Chromium*

There were four different chromium systems studied. The first consisted of a chromium-bearing sludge incorporated into concrete made using Type I cement. The other three used the same chromium-bearing sludge, but the concrete was made using Type III cement. Of the three cylinders prepared in this way, one was allowed to remain integral, another was broken into larger pieces (about 1 1/2" in diameter), and the third was broken into pieces about 1/2" in diameter just prior to immersion in the leach water. As the data presented in Figure 3 indicate, there is very little difference among the samples. Apparently, the increase in surface area among the three Type III cylinders is not noticeably affecting the leaching of chromium. This suggests that the binding is not merely interstitial entrapment. The general lowering of the metal concentration with time is not peculiar to these systems as will be seen subsequently. The implications will be discussed later.

4. *Cobalt*

Only Type I cement has been used to date in the study of cobalt leaching. The concentration of soluble cobalt entering the leach water as a function of time has been reported earlier.[5] After about 30 days the level reached about 0.004 ppm where it remained for the next 30 days and then began to diminish. The total cobalt that entered the leach water (soluble plus insoluble) was found to be about five times that of the soluble alone, or about 0.020 ppm at 60 days and 0.010 ppm at 90 days. After 100 days the entire leach water was removed from all the cobalt samples and replaced by an equal volume of deionized water. The cobalt radioactivity as a function of time for these systems was measured. The results are shown in Table 3. Both soluble and insoluble cobalt were measured. The generally lower results should be attributed to the concrete being cured for over 100 days before this new exposure. Again the tailing off of the metal concentration with time is to be noted.

5. *Manganese*

Only Type I cement has been used to test the leaching characteristics of manganese. There is no soluble manganese in the leach water during the first 60 days of leaching as reported earlier.[6] The insoluble manganese has been found to have a maximum value of about 0.04 ppm after 90 days of leaching. When the leach water was replaced after 100 days, the manganese concentrations reached about 0.037 ppm after 21 days and began diminishing to 0.024 ppm at 48 days and 0 by 116 days where they remained through 176 days. Our lower limit of detection is 0.00004 ppm in this system.

6. *Nickel*

The soluble nickel concentrations in the leach water for the first 60 days of leaching from concrete made with Type I cement were reported earlier.[7] They ranged from about 0.0015 ppm during the first 20 days to 0.005 by the fortieth day, and 0.003 at the end of 60 days. We have subsequently measured the total nickel entering the leach

Table 3

Days leaching	**7**	**21**	**48**	**116**	**143**	**155**	**162**	**172**	**176**
Conc. of cobalt in the leach water (ppm)	0.0010	0.0022	0.0066	0.0005	0	0.0003	trace	0.00005	0

Note: the lower limit of detection is 0.00004 ppm

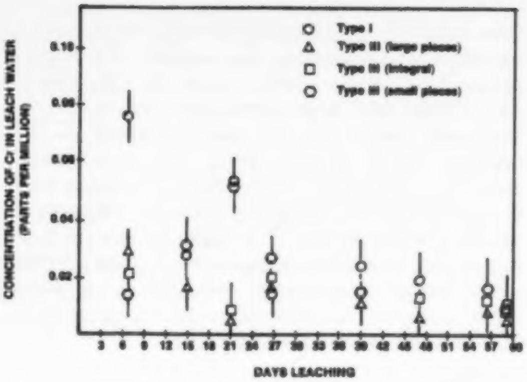

Figure 3—Concentration of Cr in leach water as a function of immersion time of sludge bearing concrete by Gamma counting.

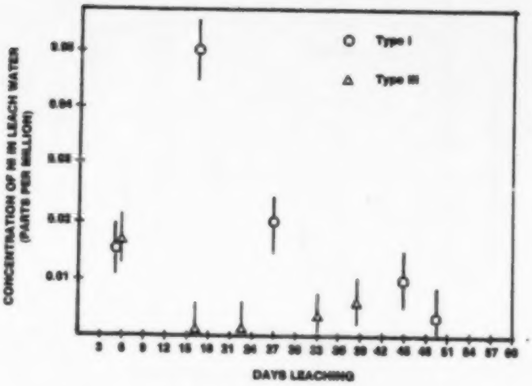

Figure 4—Concentration of Ni in leach water as a function of immersion time of sludge bearing concrete by Beta counting.

water as a function of time for both Type I and Type III cement formulations. The results are shown in Figure 4. For concrete made from Type I cement, the total nickel is about five times the soluble nickel with a maximum value of 0.035 ppm. For Type III cylinders the results are dramatically lower, in which, the total nickel concentration in the leach water never reaches 0.01 ppm.

Cylinder systems, in which, the leach water was replaced after 100 days show an initial release of nickel into the fresh leach water at a level of about 0.02 ppm after seven days. The concentration drops to 0.01 ppm in 21 days, and to about 0.005 ppm by the 165 day.

Because the ^{63}Ni emission is a very low energy β^- particle, the efficiency measurement is subject to some uncertainty. It is possible that when a refinement of this measurement is made, the results reported might have to be raised by a factor of two at the most. This would have the effect of making the highest nickel concentration 0.07 ppm.

7. *Zinc*

Previous measurements of soluble zinc entering the leach water, when type I cement was used, showed no detectable metal during the first 60 days.[8] The lower detection limit is about 0.0001 ppm. The total zinc entering the leach water as a function of time for both Type I and Type III formulations is shown in Figure 5. The Type III, high early strength cement, produces a concrete, which for zinc, allows release at the barely detectable level of slightly greater than 0.0001 ppm. Even Type I cylinders release the zinc at an extremely low level. The zinc cylinders that were reimmersed after 100 days showed an initial release of about 0.020 ppm with the concentration diminishing to 0 by the 116 day.

8. *Measurements Based on EPA Protocol for Toxicant Extraction*

One cylinder was prepared with NEP sludge to which 650 ppm manganese from $MnCl_2 \cdot 4H_2O$ was added with 1.0 μCi ^{54}Mn. After curing, the cylinder was immersed in 16 times its mass of deionized water and the pH was adjusted to and maintained at 5.0 using 0.5 M acetic acid for 6 days with constant agitation. At the end of 24 hours, there was no ^{54}Mn activity in the ambient water. At the end of 6 days, the water showed a ^{54}Mn activity of 40 counts/hr., which is equivalent to 0.008 ppm.

9. *Calcium and the Nature of Metal Binding*

The last metal to be considered with respect to its leaching from concrete is calcium. While it is generally not a constituent of electroplating sludge, it does make up about 45% of Portland cements. In hardened concrete, calcium is present in mineralized form (tobermorite, hydrogarnet, and aluminates), and as $Ca(OH)_2$.

As was reported earlier,[9] (Figure 6), a significant

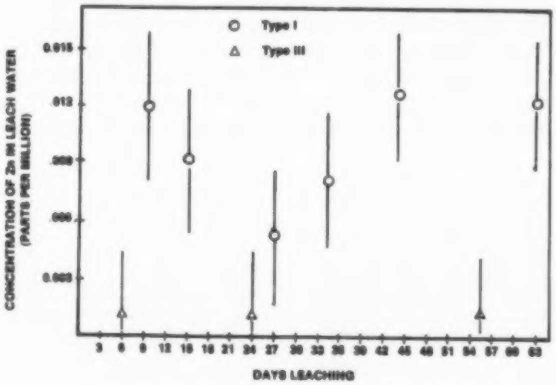

Figure 5—Concentration of Zn in leach water as a function of immersion time of sludge bearing concrete by Gamma counting.

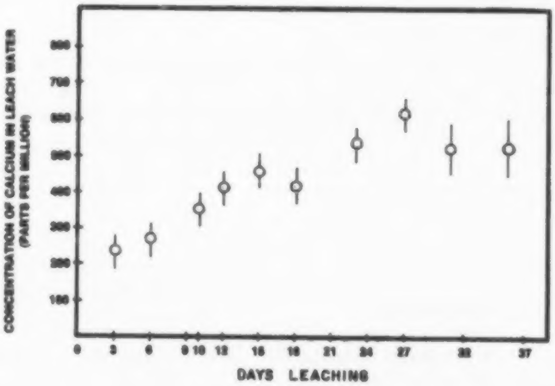

Figure 6—Concentration of calcium in leach water as a function of immersion time of sludge bearing concrete by Beta counting.

Table 4
Drinking Water Standards and Typical 50-day Leachate Metal Concentrations

	Drinking water (ppm) (ppm)	Leachate (ppm)	Without confinement (ppm)
Cadmium	0.010	0.1	65
Chromium	0.050	0.03	65
Cobalt	0.0095*	0.02	58
Manganese	0.050	0.04	33
Nickel	0.034*	0.01	30
Zinc	5	0.001	61

*Maximum concentration in finished water of 100 largest U.S. cities in 1962.

amount of calcium enters the leach water, about 1% of the total calcium content of cement. The pH of the leach water reaches 12.5 by the 25th day of immersion in the systems used in this work. Thus, if it is assumed that the entire hydroxide ion concentration is due to $Ca(OH)_2$, a calcium concentration of 630 ppm is obtained, which is very close to our radiochemically determined value of 614 ppm. Nearly 1% of all the calcium in the cement paste leached out in about 30 days. During the same period of time, less than 0.02% of the metals in the sludge leached out. The metals in the sludges used are present primarily as hydroxides. (The pH of these sludges is 8-8.5.) Even if this were not true the large excess of hydroxide ions in fresh concrete would tend to convert them to this form. Thus it seems to follow that, whereas calcium in the form of $Ca(OH)_2$ is not effectively immobilized, the other metals are. If these metals remained in the hydroxide or other nonmineralized chemical forms, they should show about the same leaching properties as calcium. The fact that they do not suggests they are at least partially mineralized. Additional evidence supporting the conclusion that compounds are chemically immobilized in concrete is to be found in the literature search of our report on phase I of the project.[10]

A puzzling aspect of the sludge-metal leaching systems is the apparent reabsorption of certain metals with extended exposure of the concrete to the same leach water. This is observed in the majority of cases. It is as difficult to dismiss it as it is to explain it. It is not due to the lessening of radioactivity with age because a correction based on half-life was made for the counting rates of all short-timed nuclides. This phenomenon is fortuitous for the purposes of this work, and it is hoped that future studies will elucidate its causes.

In conclusion it should be pointed out that the extent to which the metals studied leach into the ambient immersion water is generally of a very low level. For purposes of comparison, the maximum contaminant levels in drinking water (1974 Safe Drinking Water Act and 1962 U. S. Public Health Standards) are shown in Table 4 together with the 50-day metal concentrations determined in this study. It should be noted that the Resource Conservation and Recovery Act sets control values at 10 times these levels. A third column is included, which shows metal ion concentrations in the same volume of water if the metals were added without confinement.

FOOTNOTES

1. The Effect of Electroplating Wastewater Sludge as an Admixture on the Physical Properties of Concrete - Phase I, Report to American Electroplaters' Society, on Project No. 49, October 20, 1979.
2. Resource Conservation and Recovery Act proposed test method.
3. Chandra, R., *Introductory Physics of Nuclear Medicine*, Chapter 9, Lea and Febigger, Philadelphia, 1976.
4. Snell, A. H., ed., *Nuclear Instruments and Their Uses*, Vol. 1, Chapter 5, John Wiley and Sons, New York, 1962.

5 - 10. The Effect of Electroplating Wastewater . . .

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of this research by the American Electroplaters' Society as part of Project No. 49.

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Stabilization of Heavy Metal Wastes By the Soliroc Process

J. M. Rousseaux and A. B. Craig, Jr.*

INTRODUCTION

1.1 PROJECT OBJECTIVES

The primary objective of this study was to conduct a preliminary engineering evaluation of the Soliroc metal fixation process in immobilizing potentially hazardous pollutants contained in industrial wastes. The evaluation was designed to provide experimental data on the Soliroc process and to establish a data base for future pilot scale work. Additional project objectives include:

- Expedition of preliminary bench scale experimentation of a fixation process currently used commercially in Europe.
- Provision of sufficient data that a domestic co-sponsor for further demonstration could be attracted.
- Promotion of the transfer of foreign fixation technology which appears capable of storage or disposal of industrial wastes (especially metals) for future recovery.
- Development of in-house expertise for treatment of wastes from the EPA Testing and Evaluation (T&E) facility.
- Organization and completion of the project in a minimum time period and at minimum cost.

The project was implemented by personnel from the U.S. Environmental Protection Agency (EPA), with technical consultation by Mr. Jean Rousseaux of the Cemstobel Company in Brussels, Belgium. The contributions of Mr. Rousseaux were necessary in several phases of the experimental program, especially those dealing with proprietary aspects of the Soliroc process.

1.2 SCOPE

In order to meet the objective of the study, the following tasks were performed:

- Seven samples, representative of wastes from the electroplating industry were obtained locally (Cincinnati, Ohio).
- Raw wastes were analyzed for metals, cyanide (CN), and hexavalent chromium (Cr^{+6}).
- The Soliroc process used was designed to accommodate the study wastes and the bench-scale experimental protocol.
- Waste samples were treated with the Soliroc process.
- The EPA extraction procedure (EP) test was performed on the treated wastes.
- Compression tests were performed on treated wastes (test cylinders).
- Analytical results of stablized waste samples were compared to RCRA's EP toxicity limitations, the National Secondary Drinking Water Standards and to the raw waste analyses.

SECTION 2
BACKGROUND

The metal finishing industry generates a variety of waste materials that are potentially hazardous. Electroplating process residues, pickling acids, and wastewater treatment sludges contain cyanides and heavy metals. Two methods commonly used for disposal of the materials are landfilling and ponding; both have been practiced without any particular precautions being taken to prevent them from contaminating ground water supplies. Inorganic residues and sludges from the metal finishing industry can be chemically bound to minimize the potential for groundwater contamination by effecting a change in the chemical and physical properties of the wastes. A number of fixation techniques have been studied, including precipitation, encapsulation, asphalting, cementation, and other similar stabilization processes. A list of pertinent references is shown in Appendix A. This report discusses an evaluation of one fixation process, called the Soliroc process which was developed by Cemstobel, located in Brussels, Belgium.

2.1 REGULATORY ASPECTS

Through a number of specific provisions, the Resource Conservation and Recovery Act of 1976 (RCRA) aims to promote the protection of health and the environment and to conserve valuable materials and energy resources. Subtitle C of RCRA directs the U.S. EPA to promulgate regulations to protect human health and the environment from the improper management of hazardous waste. In accordance with that direction, EPA has promulgated the Hazardous Waste and Consolidated Permit Regulations (*Federal Register*, May 19, 1980).

More specifically, Section 267.24 of the May 19 regulation indicates that one of the most prevalent pathways by which hazardous wastes migrate to the environment and contaminate groundwater is through

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the leaching of waste contaminants from land disposed wastes. It is obvious from the history of RCRA that this type of groundwater contamination was one of Congress' primary areas of concern. EPA has addressed the problem of identifying potentially leachable wastes by developing an analytical test procedure called the Extraction Procedure (EP). The EP test is discussed more fully in Section 4.1. This test method was designed to simulate the leaching action that occurs in landfills. The simulated leachate, or extract, from the EP test is analyzed and compared with the National Interim Primary Drinking Water Standards (NIPDWS). If the extract is found to contain contaminants in excess of 100 times the maximum allowable limit set by the NIPDWS, the waste is considered hazardous.

2.2 SOLIROC PROCESS DESCRIPTION

Existing waste treatment processes precipitate metal cations as hydroxides by adding a base, usually caustic or lime, which produces an insoluble solid or sludge. However, these metallic hydroxide sludges can be resolubilized in lower pH environments, as their stability is pH dependent.

In the Soliroc process, a chemical reaction takes place between metals present in an acid solution and a siliceous reagent. During the chemical reaction, a monomer is synthesized, which then polymerizes to form an insoluble bulk mass that is believed to be suitable for landfilling.

A process flow diagram of the Soliroc process in shown in Figure 2-1. Initially, hexavalent chromium is reduced to the trivalent state to allow for further reaction in the process. During the reduction of chromium, the addition of acid is necessary to maintain the pH of the waste solution at about 1.5. For production of the monomer, a siliceous reagent is slowly blended into solution, again at a consistently low pH. The addition of waste or fresh acid is necessary to maintain the low pH.

The pH is then raised by the addition of caustic to about pH 11 to initiate polymerization. The rapid rise in pH causes a thickening of the material, and subsequent development of sludge or paste. Following the polymerization step, lime and a setting agent such as Portland cement can be added to effect coagulation and hardening before the product is placed in a landfill.

2.3 SUITABLE WASTES FOR TREATMENT BY THE SOLIROC PROCESS

Inorganic wastes, as well as polar organic wastes, regardless of their degree of consistency are reportedly treatable by the Soliroc process. Some of these types of wastes are listed below:

- Inorganic compounds

  Acids—hydrobromic acid (HBr), hydrochloric acid (HCl), nitrous acid (HNO_2), nitric acid (HNO_3), sulfuric acid (H_2SO_4), and also other less common acids; an exception to treatment potential in this waste category is hydrocyanic acid (HCN).

  Bases—potassium hydroxide (KOH), sodium hydroxide (NaOH), hydrated lime [$Ca(OH)_2$], and calcium carbonate ($CaCO_3$).

  Heavy metal—solid or liquid wastes containing heavy metals such as aluminum, antimony, silver, arsenic, barium, beryllium, cadmium, calcium, cerium, chromium (+3 or +6), cobalt, copper, tin, iron (+2 or +3), magnesium, mercury, nickel, lead, and zinc.

  Oxidizing agents—chromate, chlorate, hypochlorite, and perchlorate wastes.
- Polar organic compounds

  Wastes containing these compounds include paint sludge, phenol, fatty acid, fatty amines, alcohols, ketones, and residues from latex processing.

Table 3-1
Waste Sample Identification

Sample Waste No.	*Waste*
1	Bright dip chromate for cadmium.
2	Accumulated cyanide solution and sludge from holding tank (large automatic electroplating rack).
3	Sludge from bottom of cyanide zinc plating tank.
4	Sludge from phosphate tank and carbon from nickel filters.
5	Sludge from plant sump cleanout.
6	Alkaline cleaner sludge.
7	Waste sulfuric acid pickle liquor.

SECTION 3—EXPERIMENTAL PROCEDURES

Waste samples obtained from the electroplating industry are listed in Table 3-1. These samples were selected randomly and may not accurately represent all wastes characteristic of this industry. They are considered typical, and this small sampling group is believed to be adequate for this preliminary study.

3.1 ANALYSIS OF RAW WASTE SAMPLES

The raw waste samples were analyzed for concentrations of metals, cyanide (CN), and hexavalent chromium (Cr^{+6}). CENTEC Analytical Services performed the analyses of the raw waste samples. Results are reported in Table 3-2.

Table 3-2
Analyses Results of Raw Waste Samples

(mg/l except as noted)

Sample No.	*pH*[a]	*CN*	*Cd*	*Cr*	*Cu*	*Ni*	*Pb*	*Zn*
1	1.05	1.27	15,400	57,000	450	305	4.00	180
2	13.00	2,430	910	535	1,850	5,800	0.74	5,400
5	10.06	968	782	3,890	25,500	1,330	2,000	28,700
6[b]	13.19	33.7	35.2	440	13,800	5,660	6,580	5,030
7	<1.0	c	53.0	470	39.0	46.0	c	5,000

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[a] pH units.

[b] Metal concentrations are given in units of μg/g (wet weight of sludge), as received.

[c] Analysis not performed.

Table 3-3.
Calculated Chemical Concentration of Raw Wastes After Pretreatment[1]

Sample Waste No.	Cd	Cr	Cu	Ni	Pb	Zn
	(mg/l)					
1	15,400	57.000	450	305	4.0	180
2	600	510	1,160	3,500	0.4	5,250
5	670	3,400	21,800	1,140	1,700	25,200
6	37	450	903	3,700	4,300	5,010

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[1] Pretreatment consisted of the addition of Sample 7, sulfuric acid pickle liquor (see Table 3-1).

3.2 WASTE ACCEPTABILITY AND PREPARATION

Some wastes were pretreated for Soliroc processing. Wastes containing cyanide (Samples 2, 3, 5, and 6) were chlorinated to destroy the cyanide complexes in the wastes. Following chlorination, the solution was acidified to pH 2 by adding pickle liquor (Sample 7). The chemical concentrations of pretreated Samples 1 through 6 were calculated, and results are given in Table 3-3.

After raw waste characterization and preliminary screening of the wastes by data review, Samples 3 and 4 were eliminated from further evaluation. Waste 3 contained elemental zinc in amounts that prohibited obtaining a low steady pH without production of hydrogen gas (H_2) at potentially hazardous levels. Consequently, Sample 3 was discarded. Waste Sample 4 was discarded because high carbon content interfered with the measurement of pH.

Elimination of these samples in this study does not necessarily imply that these two waste types are unacceptable for treatment by the Soliroc process. They were eliminated because of limitations in the scope of this preliminary study. The purpose was not to prove universal application of this process, but to develop data as a foundation for further investigations. On this basis, wastes that were not readily compatible with this process were not tested.

The four remaining samples (1, 2, 5, and 6) were blended in a ratio that is critical to the success of this process. The basis for determining this ratio was developed by Cemstobel and is proprietary information. The wastes were blended in the proportions shown in Table 3-4.

The resultant metal concentrations were calculated for the blended waste, with results as shown in Table 3-5. As a quality assurance check, a sample of the blended waste was titrated with caustic (NaOH) to confirm or invalidate the calculated total metal concentration. (The assumption here is that at pH 10.5 all metals are hydroxylated and the measured equivalents of NaOH will indicate total equivalents of cation metals in solution prior to titration and precipitation with caustic). This is a relatively inaccurate measurement, yielding values that can vary with the selected end point and with sample characteristics. This analytical check resulted in 1.44 cation equivalents per liter; the calculated metal content was 1.25 cation equivalents per liter. These values are considered reasonably comparable, and are included here as a means of verifying the calcuated concentration values.

Table 3-4
Blended Waste Composition

Sample No.	Proportion	Waste identification
1	0.5	Bright dip chromate for cadmium
2	1.0	CN solution and sludge from holding tank on automatic rack
5	0.5	Plant sump cleanout
6	1.0	Alkaline cleaner sludge

Table 3-5
Calculated Concentrations (mg/l) of Metals in the Blended Waste

Cd	2,890
Cr	10,390
Cu	7,100
Ni	2,640
Pb	1,710
Zn	7,650

3.3 FIXATION OF BLENDED WASTE

After blending of the wastes, the sodification treatment procedure was followed according to the process description given in Section 2.2. The figure shown in that discussion (Figure 2-1) illustrates the experimental procedure. However, minor modifications were made to the process and are discussed below.

In the chromium reduction step, sodium sulfite, Na_2SO_3 was continuously added to the blended waste to act as the reducing agent. An acid pickle liquor (Sample 7), supplemented by white sulfuric acid, was added to maintain the pH at 1.5. Addition of the siliceous reagent, and formation of the silicic acid solution were performed in a reaction mixer. Polymer initiation, by addition of caustic, was also performed in the mixer. Addition of lime and/or cement followed, and the mixer was emptied into a suitable container for further testing.

3.4 EVALUATION OF THE SOLIROC PROCESS

Six experimental runs were performed, some with variations of the standard process. Five experimental runs used the blended waste sample, and one (Run 6) was performed on raw pickle liquor. Table 3-6 outlines the variations applied to all runs. Runs 1 and 5 were duplicates, in which the process was performed as described earlier. In Run 2 addition of the pickle liquor

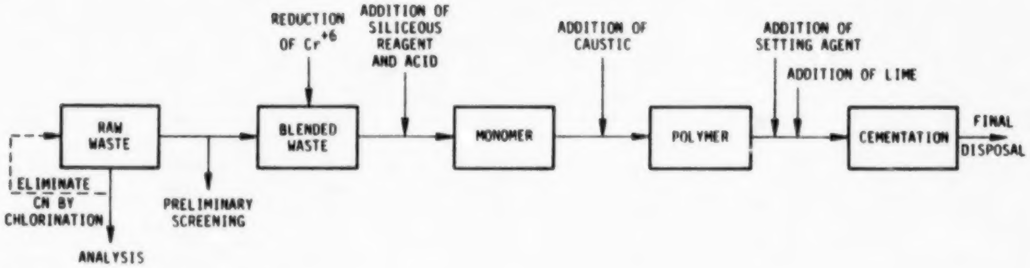

Fig. 2-1.—Flow diagram of the Soliroc process.

was omitted. In Run 3, the proprietary siliceous reagent was omitted. Run 4 was similar to Run 2 except for the cementation step; Portland cement was added in the cementation phase of Run 4, whereas no cement was added during Run 2.

3.5 THE EPA EXTRACTION PROCEDURE

Following is a brief description of the EP test used as the analytical basis for this study.

A 100-gram sample (approx.) was prepared for extraction by reducing the particle size (by crushing, cutting or grinding) so that the sample material would pass through a standard 9.5 mm (3/8-in.) sieve. After being weighed, the solids were placed in an extraction container, to which 16 grams of water were added for every gram of solids. This mixture was stirred sufficiently to assure that all sample surfaces were continuously brought into contact with the well-mixed extraction fluid and to prevent any stratification. The pH was adjusted to 5.0 ±0.2, by use of 0.5 N acetic acid. The total addition of acetic acid was limited to 4 ml per gram of solid, beyond which no more was added. The extraction was maintained between 20° to 40° C (68° to 104° F) for 24 hours. The mixture was separated as before into solid and liquid components. The liquid was diluted with distilled water to a total volume equal to 20 times the weight of the initial solid materials. This liquid was the "extraction procedure elutriate," which was analyzed for metal ions.

Table 3-6
Experimental Runs

Experiment run No.	*Waste blend*	*Acid added (Step 2)*[a]	*Cementation (Step 4)*[a]
1	1,2,5,6	Pickle liquor and H_2SO_4	Lime and setting agent
2	1,2,5,6	H_2SO_4	Lime and setting agent
3	1,2,5,6	Pickle liquor	Lime
4	1,2,5,6	H_2SO_4	Portland,[b] lime, and setting agent
5	1,2,5,6	Pickle liquor and H_2SO_4	Lime and setting agent
6	Pickle liquor	Not applicable	Portland,[b] lime, and setting agent

[a] Step numbers refer to the process description in Section 3.3.
[b] Portland cement.

SECTION 4
TEST RESULTS

In addition to the planned EP test for evaluation of the stabilized wastes, two additional test series were conducted, the results of which are also presented here. The Cemstobel Laboratory in Belgium performed metals analysis on samples referred to as core dips. A core dip is distilled water in which the stabilized wastes (Runs 1, 2, 4, and 5), in the form of solidified cores, were allowed to soak for about 30 days. This test was performed to allow comparision with the EP test results.

The second additional test series involved determination of the unconfined structural stability of the cemented wastes. Three cores (6 in. diameter and 12 in. long) from each experimental run were aged from 61 to 66 days and submitted to an independent testing laboratory. Each core was compressed to the failing point, and the total load recorded. The total compressional load required to cause failure, relative to the cross sectional area of the core, yields a value for compressive strength in units of pressure (psi).

4.1 EP RESULTS

Data obtained in the EP test are shown in Table 4-1. The maximum allowable acetic acid column is shown, in accordance with the limitation of 4 ml 0.5 N acetic acid per gram of solid sample. It is noteworthy that the maximum allowable volume of acetic acid was required

Table 4-1
EPA Extraction Procedure Data

Run No.	*Stabilized waste sample size, g*	*Initial pH of EP extract*	*Final pH of EP extract*	*0.5N HAc*[a] *added, ml*	Max. *HAc*[a] *allowable, ml*
1	99.5	10.1	7.2	398.0	398.0
2	99.4	10.7	6.6	397.6	397.6
4	105.0	11.4	9.1	420.0	420.0
5	100.6	10.4	7.3	402.4	402.4
6	102.5	11.0	9.5	410.0	410.0

[a] HAc = acetic acid.

Table 4.2
Analyses of EP Extracts

Run No.	*Cd*	*Cr*	*Cu*	*Ni*	*Pb*	*Zn*
	mg/l					
1	5.60	0.10	0.28	1.30	0.013	34.8
2	2.30	0.27	0.64	0.95	0.016	5.00
4	0.10	0.13	0.06	0.15	0.006	0.41
5	2.70	0.18	0.36	1.15	0.017	25.0
6	<0.01	0.50	0.05	<0.10	0.008	0.50
Maximum allowable concentration	1.0[a]	5.0[a]	100.[b]	c	5.0[a]	500.[b]

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[a] Characteristic of EP toxicity from RCRA (100 times NIPDWS).
[b] 100 times the secondary maximum contaminant level.
[c] Nickel is not regulated by the primary or secondary drinking water standards.

in every case, an indication of the strong alkalinity of the setting agent and Portland cement added during the stabilization of waste samples.

The results of analyses of the EP extracts are shown in Table 4-2. The maximum allowable concentrations for each metal were determined from the promulgated RCRA regulations for cadmium, chromium, and lead and from the secondary drinking water standards for copper and zinc. The principle of an attenuation factor of 100 that is the basis for the RCRA maximum contaminant levels was applied to the secondary drinking water standards.

4.2 RESULTS OF ADDITIONAL TEST RESULTS

Results reported by Cemstobel for analysis of metal concentrations in the core dip samples are shown in Table 4-3. Lead concentration was not determined on these samples. Results of the compressive strength tests are shown in Table 4-4.

SECTION 5
DISCUSSION OF RESULTS

A comparative presentation of the analytical results from the EP tests is shown in Figure 5-1. Except for cadmium, the EP extracts gave concentrations of the metals below the maximum allowable concentration. Only one experimental run stabilized cadmium satisfactorily. This observation leads to the preliminary conclusion that the Soliroc process, as it was modified for this study, may not be capable of stabilizing wastes containing cadmium in the range of 2000 to 3000 mg/l. The contaminant that appears most easily stabilized is lead, which however, was present in the blended waste at the lowest concentration of all the metals. Results of the EP extract analysis for lead average 0.013 mg/l, well below the maximum allowable concentration.

Table 4-3
Analyses of Core Dip Samples

Run No.	*Cd*	*Cr*	*Cu*	*Ni*	*0]23*
	(mg/l)				
1	0.004	0.04	0.5	0.31	0.23
2	0.01	0.04	0.3	0.46	0.007
4	0.3	0.04	0.14	0.21	0.03
5	0.005	0.02	0.12	0.28	0.02

Table 4-4
Results of Compressive Strength Test

Run No.	*Age days*	*Total load, pounds*	*Unit load, psi*
1	66	150	5
1	66	250	9
	66	250	9
2	66	2,000	71
	66	1,900	67
	66	1,800	64
4	64	4,250	150
	64	4,500	159
	64	4,500	159
5	63	500	18
	63	500	18
	63	650	23
6	61	1,500	53
	61	1,550	55
	61	1,500	53

The results of Run 6, in which pickle liquor (without additional waste) was used as the starting material for the process, are not shown on Figure 5-1 for two reasons. First, the metal concentrations in the starting materials are not comparable, and second, the EP extract analyses for Run 6 yielded relatively low metal concentrations (see Table 4-2). The data indicate that the Soliroc process is adequate in immobilizing potentially hazardous constituents of sulfuric acid pickle liquor. The cadmium concentration in the EP extract from Run 6 was well below the standard, however the initial concentration of cadmium in the pickle liquor is more than 50 times lower than the calculated concentration in the blended waste samples.

Figure 5-1 can be examined further to evaluate the effects of different modifications to the Soliroc process in stabilizing identical blended waste samples. The EP extract analysis for Run 4 gave the lowest concentration for every metal except chromium. This observation leads to a preliminary conclusion that either the use of only H_2SO_4 as the acid additive or the addition of Portland cement improves the stabilizing capabilities of the Soliroc process. As a means of distinguishing between the individual effects of these two process modifications, a

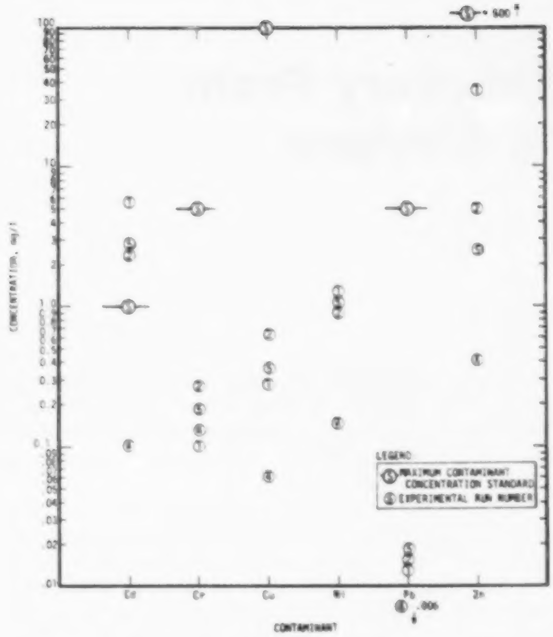

Fig. 5-1—Concentrations of metal contaminants in EP extracts (by experimental run number).

comparision of data from Runs 1 and 5 (duplicates) and Run 2 yields a useful observation. The use of either H_2SO_4 (only) or pickle liquor plus H_2SO_4 as the acid additive does not appear to consistently improve the stabilizing capability of the Soliroc process. Therefore, the use of waste acid does not adversely affect the process. Also, the addition of Portland cement appears to significantly improve the stabilization of certain metals.

A comparison of the core dip analyses with the EP tests results yields predictable observations. Metal concentrations in the core dip samples were consistently much lower than those found in the EP extracts. It is believed that this is primarily due to the relative aggressiveness of the EP analytical procedure when compared to the core dip experimental protocol. Additionally, results of the core dip analyses do not support the above stated conclusion that Portland cement improves the stabilization of certain metals. The reason for this is not understood.

Results of the compressive strength tests also yield predictable observations and conclusions. The addition of Portland cement in the cementation step improves the structural stability of the hardened material.

The results of this study provide benchmark data on which to base further engineering investigations regarding the capabilities of various stabilization or fixation processes. Before more definitive conclusions can be drawn, detailed experimentation with other wastes, processes, and process modifications is needed. It is suggested here that organizations such as the EPA, the American Electroplaters' Society, the Portland Cement Association, and other involved with the stabilization of potentially hazardous materials combine their efforts in conducting a more comprehensive study of this important subject.

APPENDIX A

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Routes to Metals Recovery From Metal Finishing Sludges

Anil Mehta*

The process wastewaters from the electroplating industry contain cyanides and heavy metals. Because of their detrimental effect on the environment, discharges are regulated by the federal, state, county, or city ordinances, thus necessitating installation of treatment technologies. One of the treatment technologies widely in use already and more likely to be installed is neutralization and precipitation technology which destroys the cyanide and removes the heavy metals as hydroxides. This treatment is shown in Figure 1.

The sludge is commonly disposed of in landfills. This practice is coming under greater scrutiny by the regulating authorities, primarily due to the presence of the heavy metal hydroxides. The heavy metals may leach due to changes in their environment. The leached metal may report to the surface runoff waters, or to the groundwaters or both. To prevent any leaching of the metals, secure and chemically maintained land disposal sites are required. The cost of disposal thus becomes greater not only because of the heavy metal presence but also because the secure landfill sites are expensive to create and maintain. Finally, such sites may not become available because of resentment on the part of the community itself.

Since a landfill site has a finite capacity, sludges, in the form generated at the electroplating plant, may not be acceptable to the operator of the site. Such sludges usually contain about three percent solids requiring volume reduction by dewatering to conserve his capacity. Dewatering requirements necessitate installation of a filter press or a centrifuge. This problem from process wastewater to the final disposal is summarized in Figure 2.

If the landfill site is not properly maintained, certain problems arise:

1. Contamination of the surface and the ground waters by the heavy metal migration when and if the pH conditions change.
2. Permanent loss of metals if the site undergoes a physical change, i.e., it becomes a parking lot.
3. Dilution in metal contents if the sludges are mixed with other types of waste material.

What makes these hydroxide sludges potentially hazardous is the presence of the heavy metals. A typical sample composition range in shown in Table 1.

Trying to immobilize the heavy metals in a sludge by any one of the fixation techniques would add to the cost of the final disposal and still promote land application of heavy metals. Under RCRA, severe restrictions may be encountered by land disposal.

Recovery and recycling is practiced by the metal industry at significant levels. But this practice is restricted in the sense that it applies to only the pure solid waste. Thus, recycling constitutes about 20 percent of the total copper metal available in the market recovered from pure solid scrap. This is the scrap that needs simple melting and refining. The scrap comes from two sources: capital goods such as buildings, industrial machinery, etc., or consumer goods such as automobiles, appliances, etc.

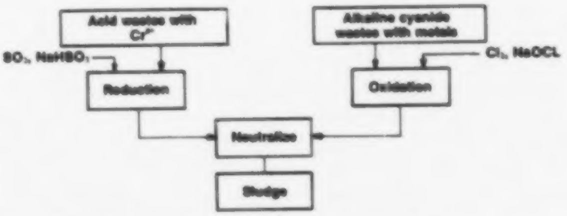

Fig. 1—Cyanide destruction and heavy metal removal.

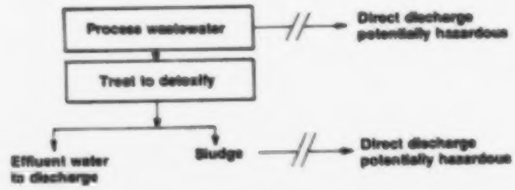
Process wastewater
Direct discharge potentially hazardous
Treat to detoxify
Effluent water to discharge
Sludge
Direct discharge potentially hazardous

Fig. 2—Wastewater discharge problem.

Table I
Hydroxide Sludge Composition in %*

Copper	2-6
Nickel	2-6
Zinc	2-10
Cadmium	2-6
Chromium	5-20

*at three percent solid contents

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On the other hand, metal losses on a permanent basis are also tremendous. Of all the recorded production of copper in this country, 72.5 million short tons, about 60% are traceable as being in use presently. Forty percent or 29 million short tons (58 billion pounds) are lost permanently due to wear, abrasion, chemicals, fabrication, etc. At today's prices, this loss amounts to 58 billion dollars figured at the price of finished copper product which is wire bar grade copper cathode. The loss is staggering when figured in terms of the finished capital and consumer goods.

Another example of this loss is provided by the electroless copper plating industry. The printed circuit board platers comprise ten percent of all the electroplaters in business. They generate about a million gallons of liquid waste (sludges) annually. If one gallon of this sludge weighs about ten pounds and contains ten percent copper, about a million pounds of copper are contained in this sludge annually. Disposal of such waste is not always carried out with recovery at a later date in mind, so a very significant amount is lost each year.

The electroplaters do not treat these sludges for metal recovery for many reasons. Recovery is an uneconomical proposition in terms of capital and operating costs, is an incompatible operation, and individually the quantities generated are not large enough to justify a recovery system.

An alternative to any individual treatment for metal recovery is the concept of Centralized Waste Treatment Facility (CWTF). Such a facility would require no direct participation from the platers, would pose no operating problems to the platers, and would certainly solve the discharge problem for the entire industry. By pooling it together, the quantities to treat may be large enough to make the recovery operation economically attractive.

Nontreatment of these hydroxide sludges will always present two main concerns: potential water pollution, and resource loss. With resource recovery and conservation aims in mind, any treatment to recover the heavy metals would alleviate the toxic hazard problem associated with the disposal of the heavy metals.

Possibility of hydroxide treatment for metal recoveries fall into two categories: wet and dry. In wet processes, separation reactions are carried out usually at atmospheric temperatures and pressures. In dry processes, separation reactions take place at elevated temperatures. The former processes are generally classified as hydrometallurgy and the latter as pyrometallurgy.

Pyrometallurgical treatments for segregated and selected sludges are:

- Direct recycle to a smelter after dewatering,
- Direct recycle to metal alloy industry on a small basis.

Troubles with pyro processes are that for economical feasibility the operation would have to be on a very large scale, and that concentrated feed material is required. The hydroxide sludges fail to meet these two requirements. Under pyrometallurgical treatment, above two above possibilities are presently available and further discussion is not presented.

Hydrometallurgical treatments for mixed and segregated sludges are:

- Aqueous dissolution of metals by leaching.
- Recovery of individual metals or metal compounds from this solution.

There are certain advantages for using hydrometallurgical processes. Metals may be won directly from the solution by concentration, electrolysis, or hydrogen reduction. Fuel requirements are low as the processes are carried out usually at low temperatures. Disadvantages are that solution purification and concentration upgrading may be absolutely necessary before metal recoveries are possible. But this particular branch of metallurgy is going to see much use as new techniques are developed. Building mini-smelters is very uneconomical while building a mini hydrometallurgical plant is becoming a matter of fact.

Since any commercial practice would naturally take into account the profitability as the primary objective, the treatment of the hydroxide sludges is being offered with that objective in mind. This requires that the process be specific, reproducible, and controllable. The process should also be possible with a minimum number of unit operations and unit processes. The treatment of hydroxide metal sludges is now considered in terms of the unit operations and unit processes. These two depend on the chemical state and also on the physical environment of the metals. Electroplating wastes, after the hydroxide neutralization, will consist mainly of metal hydroxides such as $Cu(OH)_2$, $Ni(OH)_2$, $Cd(OH)_2$, $Zn(OH)_2$, etc. With lime neutralization, the sludge will also contain calcium salts. A range of composition is provided in Table I.

The following reagents are solvents for many minerals and metallic constituents: sulfuric acid, ferric sulfate, ammonia and ammonium carbonate, sulfur dioxide, ferric chloride, hydrochloric acid, and nitric acid. The order given is about that of their importance. Metal winning from solutions by such operations as cementation or electrolysis is commonly practiced from the metal sulfate solution.

Sulfuric acid is the most important leaching reagent. Main advantages for its use are the cost, minor corrosion problems, and attacking many metal forms. Its main disadvantage is that it sulfatizes everything, which does not provide any selectivity. Ferric sulfate may be obtained cheaply from spent pickle liquors. Its primary function is to provide a sulfate solution. Ammonia and ammonium carbonate may be the most suitable reagents for hydroxide sludges because they possess better selectivity for solubilizing metal constituents in a hydroxide sludge. But the reagent cost is very high and their recovery in the process would be mandatory from an economical point of view.

Primary aim for a solvent is to bring the metal or metals into solution from which individual separations are made. This operation provides pure solutions, with major impurities out of the way. For leaching, the following steps, as shown in Figure 3, may be necessary.

Leaching of hydroxides by either sulfuric acid or ammonia will provide lean solutions. Copper may be recovered from lean sulfate solutions by cementation. Iron will displace copper quantitatively from a solution. The product, although rich in copper, may be highly contaminated with iron so that only a smelter may be able to handle it. A technique which is becoming widely accepted for concentrating solutions is one of ion exchange. The ion exchange medium may be solid or liquid. Generally speaking, concentrating by solid organic resins is known as ion exchange (IX) and by liquid organic resin is known as solvent extraction (SX).

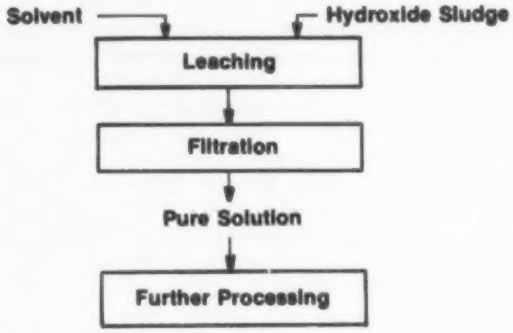
Solvent
Hydroxide Sludge
Leaching
Filtration
Pure Solution
Further Processing

Fig. 3—Leaching of hydroxide sludge.

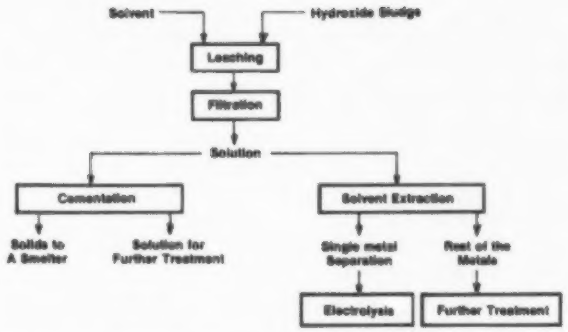
Solvent
Hydroxide Sludge
Leaching
Filtration
Solution
Cementation
Solvent Extraction
Solids to A Smelter
Solution for Further Treatment
Single metal Separation
Rest of the Metals
Electrolysis
Further Treatment

Fig. 4—Generation and treatment of pure metal solutions.

Ion exchange saw a tremendous application in uranium metallurgy. The solvent extraction technique is becoming accepted in copper metallurgy. The acceptance is on such a large scale that the future may see its application widely spread in areas where the ore grade has kept going down or residual metallic wastes are to be treated. The scheme for obtaining pure solutions in Figure 3 may be expanded now as in Figure 4.

For sulfuric acid leach solutions, copper may be recovered from the polymetal solution by cementation under oxidizing solution. The cement copper may be sold directly to a smelter or releached for electrolysis. Other metals are selectively precipitated after iron removal and may be recovered as pure metals or metal compounds. Electrolysis regenerates the sulfuric acid for recycle which is a very important factor in economic evaluation because regeneration is part of the process requiring no additional or extra regeneration equipment installation.

Copper may also be removed from the polymetal sulfate solution by solvent extraction. Copper then is removed by electrolysis. Other metal recoveries may be achieved by further solvent extraction or by cementation with zinc.

If ammonia leach is employed, metals such as copper, nickel, and zinc are selectively brought into solution as ammines from the hydroxide sludges. Other impurities such as iron and calcium are left behind as solids. Copper may be removed from this polymetal solution by solvent extraction, stripping with sulfuric acid, and electrowinning. Other metals are further treated for separation. Additional reagent recovery equipment is necessary.

These are two basic routes for metal recovery from hydroxide sludges that have been looked into extensively by various parties. Metal recoveries will become practically feasible if the aim is to provide pure solutions with a minimum number of unit operations and unit processes. A cost study was developed based on sulfuric acid leach of metal hydroxide sludges with the use of solvent extraction for solution concentration and electrolysis for metal recovery.

Generally, there are three types of liquid wastes in a

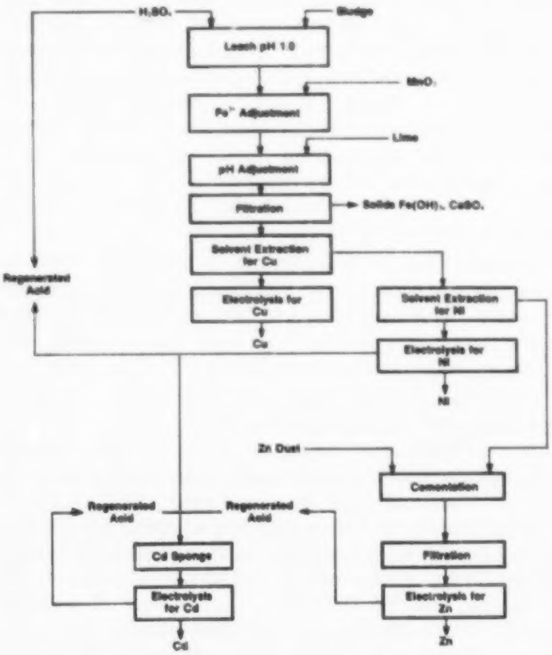
H_2SO_4
Sludge
Leach pH 1.0
MnO_2
Fe^{3+} Adjustment
Lime
pH Adjustment
Filtration
Solids $Fe(OH)_3$, $CaSO_4$
Solvent Extraction for Cu
Electrolysis for Cu
Cu
Regenerated Acid
Solvent Extraction for Ni
Electrolysis for Ni
Ni
Zn Dust
Cementation
Regenerated Acid
Regenerated Acid
Cd Sponge
Electrolysis for Cd
Cd
Filtration
Electrolysis for Zn
Zn

Fig. 5—Mixed Metal Hydroxide Sludge Recovery Process.

Table 2
Sludge Value Calculations - 3% Solids

3% Solids = gms/liter = 0.26 #/gallon

0.26 #/gallon × 5% Cu × \$1.25/# = 0.016
" × 5% Ni × \$3.0/# = 0.039
" × 10% Zn × \$0.37/# = 0.010
" × 5% Cd × \$3.50/# = 0.046
0.111 \$/gallon

Sludge Vol. Gallons	*Sludge Wt.* Pounds (S.T.) @ 8.62 #/Gal.*	*Solids Pounds (S.T.)*	*Contained Value*
1,000	8,620 (4.31)	260 (0.13)	111
5,000	43,100 (21.55)	1,300 (0.65)	555
10,000	86,200 (43.10)	2,600 (1.30)	1,110
25,000	215,500 (107.75)	6,500 (3.25)	2.775
50,000	431,000 (215.50)	13,000 (6.50)	5,550
100,000	862,000 (431.00)	26,000 (13.0)	11,100

*0.26# Solids/gallon
= 0.26# solid to 1 gallon water
= 0.26 + 8.36
= 8.62 #/gallon

Table 3
Sludge Value Calculation - 20% Solids

20% Solids = 250 gms/liter = 213 #/gallon

2.13 #/gallon × 5% Cu × \$1.25/# = 0.133
" × 5% Ni × \$3.00/# = 0.320
" × 10% Zn × \$0.37/# = 0.079
" × 5% Cd × \$3.50/# = 0.373
0.905 \$/gallon

Sludge Vol. Gallons	*Sludge Wt.* Pounds (S.T.) @ 10.5 #/Gal.*	*Solids Pounds (S.T.)*	*Contained Value (\$)*
1,000	10,500 (5.25)	2,130 (1.07)	905
5,000	52,500 (26.25)	10,650 (5.33)	4,525
10,000	105,000 (52.50)	21,300 (10.65)	9,050
25,000	262,500 (131.25)	53,250 (26.63)	22,625
50,000	525,000 (262.50)	106,500 (53.25)	45,250

*2.13 #/gallon solids
= 2.13 # solid to 1 gallon water
= 2.13 + 8.36
= 10.5 #/gallon

Table 4
Total Contained Values for 10,000 Gallons of Sludge/Day

@ 3% solids

Total sludge weight = 43.1 S.T.
Total contained value = \$1,110
304 working days = \$337,440/year

@ 20% solids

Total sludge weight = 50.5 S.T.
Total contained value = \$7,220
304 working days = \$2,194,880/year

Above values calculated witn commodity metal market prices.

Table 5
Fixed Capital Costs for a Leach - Solvent Extraction - Electrowinning Complex

	\$/Annual Ton Cu	
	1975	*1980*[1]
Leaching Facility	90.7	182.5
SX Plant	635.0	1227.3
Electrowinning Plant	408.2	821.1
Melting and Casting	45.4	146.9
	1,179	2,377

Solids @ 20% witn 5% Cu on a dry basis

10,000 gallons/day sludge with 21,300 #solids/day
Annual capacity=

$$21{,}300\ \frac{\#\ \text{solids}}{\text{day}} \times 5.0\%\ \text{Cu} \times 304\ \text{days} \times \frac{\text{ton}}{2{,}000\ \text{lb}} = 162\ \text{tons Cu}$$

[1] 15% inflation with 1975 as the base year.

plating shop: (1) rinse waters, (2) spent baths, and (3) spills.

Spent baths are collected separately. They require only cyanide destruction and thus become concentrated metal solutions. Rinse waters and spills are treated conventionally for heavy metal precipitation. This presorting provides two distinct feed materials: (1) a concentrated solution, and (2) a hydroxide sludge. The leach solution from hydroxide sludge leaching with sulfuric acid is mixed with the spent bath solution for metal extraction. A generalized scheme is shown in Figure 5. The sludge was originally at 3 - 4% in solids. Cost analysis has compared the sludge at 3% solids with one at 20% solids in terms of metal values contained in the product, tables 2, 3, and 4. Fixed capital costs are provided in Table 5.

Annual direct operating costs for 1 ton of copper for the leach - SX - electrowin complex were \$1,272 per annual ton of copper in 1975. At 15% inflation rate, these will be \$2,560 per annual ton of copper in 1980.

For 162 tons of Cu, annual direct operating cost = \$414,720.

Annual indirect operating costs for 1 ton of copper for the leach -SX- electrowin complex were \$544 in 1975. At 15% inflation rate, these will be \$1,094 in 1980.

For 162 tons of Cu, annual indirect operating cost = \$177,228

Total cost of producing copper from hydroxide sludges is then 2,560 ÷ 1,094 = \$3,654 per ton which is about \$1.80 per pound, or a total of \$583,200 per year.

Indirect operating costs include costs for borrowing capital, depreciation, and income taxes, etc.

Total revenue from 162 tons of copper @ \$1.00 per pound is \$324,000 per year as compared to \$583,200 in cost to produce it. There is a net loss in the operation unless the credits from nickel, zinc, and cadmium are added to the revenues. Although their recovery will add to the direct and indirect operating costs, and working capital, much of this cost will have already been applied to copper.

This credit consideration will need to be examined closely before attempting to authorize or not authorize capital spending. Preliminary studies show that the operation of metal recovery from the hydroxide sludges would be profitable after considering the credits to be realized. There certainly is an economic incentive for treatment of the hydroxide sludges. The treatment would then not be limited to the electroplating industry alone, but would look into treating nonferrous wastes from other industries too.

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Solvent Recovery For the Smaller Company

C. Kenneth Claunch*

INTRODUCTION

Due to new environmental laws and the increase in crude oil prices, as a result of OPEC, the cost of all organics, including solvents, has risen dramatically in recent years. For the smaller company, this has been particularly burdensome, since it is very difficult, as is usual with a smaller company, to pass on these remarkable costs.

Referring to the table below, it is a fact that in 1973 (prior to OPEC), typical solvent, in this case acetone, cost (net) about 30¢ a gallon, composed of its purchase cost and disposal cost. The latter in those days was a credit (!). These costs have risen to the range of $3.00 a gallon today, and it appears to be rapidly going to $5.00 a gallon.

COST OF SOLVENT

(This Example: Acetone, $ per Gallon)

	1973	*1976*	*1980 (Feb)*	*Projected*
Purchase	.35	1.35	2.31	3.15 - 4.20
Disposal	(.05)	(.20)	.66	.66 - 2.00
Net Cost	.30	1.05	2.97	3.71 - 6.20

We are, thus approaching the day when the use of industrial (organic) solvents is analogous to the use of lobster at home - 'A thing of the past; too expensive!'

Solvent recovery processes - usually an adaptation of distillation - have been utilized for quite some time. But these processes have been for high volume treatment of contaminated solvents. Basically, these tend toward the 1,000 gallon/hour range and often involve fractional distillation.

Experience and processes for treatment of smaller volumes of solvent contamination have been lacking. With price increases and the enormous disposal responsibilities facing us, recovery of solvent, for the small volume user, needed attention. This paper outlines proven, successful experiences and processes for smaller scale (one drum per week to one drum per hour) solvent recovery systems. These processes are very economical, often having returns on investment, ROIs, in the 100 to 400 percent range.

During this presentation we will show you a way not only to save large numbers of dollars in avoiding the purchase of new solvents, but of even greater importance, a method to comply with the new environmental laws on hazardous chemicals on which the EPA is currently issuing regulations. Solvents contaminated with paint, grease, and other miscellaneous materials are identified specifically by the EPA as "hazardous materials"* and must be handled according to the new strict laws. The 1976 Resource Conservation and Recovery Act makes us liable for these materials cradle-to-grave on, apparently, a "strict liability" basis (i.e., if there is a violation by others, the generator is responsible 'no matter what he did right'!). What makes this situation even more unique is that there are fines (to 25,000/day) and a *personal* CRIMINAL liability!

Generally, organic liquid wastes fall into four categories. One, oil sludges, represent about one-fourth of the total in this country and are not particularly noxious. There is the category generally called pasty miscellaneous organic chemicals, and these cover about one-third of organic liquid wastes. These materials are by-products from organic synthesis, still bottoms, and the like. They are usually viscous, high boilers, and often very toxic (e.g. Love Canal contained distillation sludge from pesticide manufacture). The third major category, industrial solvents, also represents about one-third-plus of the wastes. We will be talking about these throughout this presentation. The source of contaminated industrial solvents is many, many users - small companies like yourselves, and generally used for wash-up operations. Chlorinated and nonhalogenated solvents are involved. They are very expensive. Their costs are presently ranging from a rare $2.00 to as high as $12.00 per gallon. The fourth category of organic liquid waste is of quite well known materials. These are pesticides, rodenticides, PCBs, and other particularly noxious and/or well publicized** toxic chemicals. This fourth category represents only 1 to 2 percent of the U.S. organic wastes total.

SOLVENT RECOVERY WITH STANDARD STILL

(Nominal rate: 4 drums/shift)

How It works:

This batch type solvent recovery technology is the not-new method of differential distillation combined with recently developed techniques to allow the controllable boiling and removal of valuable solvents from residues that can range in viscosity up to 10,000 CPS.

Basically the still operates by heating contaminated solvents to form vapors of pure solvents, condensing

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* Federal Register, Vol. 43, No. 243, p. 58957, 250.14 (a).

** Publicity often increases the perceived toxicity of a chemical, which, in essence, makes it more toxic from a regulatory standpoint!

them outside the still to collect a clear, purified solvent mixture. The difficult aspect of this operation is that the residue in the still is becoming more and more viscous. The gist of the technology of this still is (1) to have instruments that can readily alert the operator when the viscosity or thickness of the residue in the still is beginning to increase. In lay terms, we want to continue to boil the material until the residue is about the consistency of catsup and not go as far as the consistency of peanut butter.

The viscosity instrument is quite simple and non-plugging (very, very important when dealing with such thick medias). When the material is too thick, shut-down is automatic.

It is also essential (2) to have a means of eliminating caking on the heated wall. A patent pending device that, in essence, scrapes the wall with a non-wearing, non-sparking razor-blade-like knife every five seconds is utilized. Heat transfer coefficients of over 200 Btu/hr-ft^3-°F can be maintained even to viscosities of over 5,000 centipoise.

Figure 1 shows a flow diagram of the still. (A) is the boiling chamber into which the contaminated solvent is pumped. Heat is supplied from a boiler at (E) to the steam jacket at (B). The internal scraper is indicated by (D). The vapors of solvent(s) exit the unit at the top and are condensed by an air cooled or water cooled condenser (C) filling the clean solvent drum to the left. The highly reliable controls at (E) tell the operator that his viscosity is satisfactory.

In actual operation the operator does the following: Into an empty still he pumps *two* 55-gallon drums of contaminated solvent. He turns on the still and then can leave the area. The unit will boil and condense one drum and shut itself off. When the operator returns, he pumps in another drum of contaminated solvent and places an empty clean drum under the condenser. Again, he turns on the still and leaves the area. Typically, this will continue until 10 drums have been added and nine drums of clean solvent(s) recovered, a 90% recovery. The remaining one drum residue is drained out the bottom of the still into a sludge drum. This sludge can be disposed of by EPA approved methods (e.g. certain landfills) or by processing it in a manner to be discussed later in this presentation.

Economics

The return on investment from this process is often startling. If a company has JUST one drum per day of contaminated solvent, the return on investment (ROI)

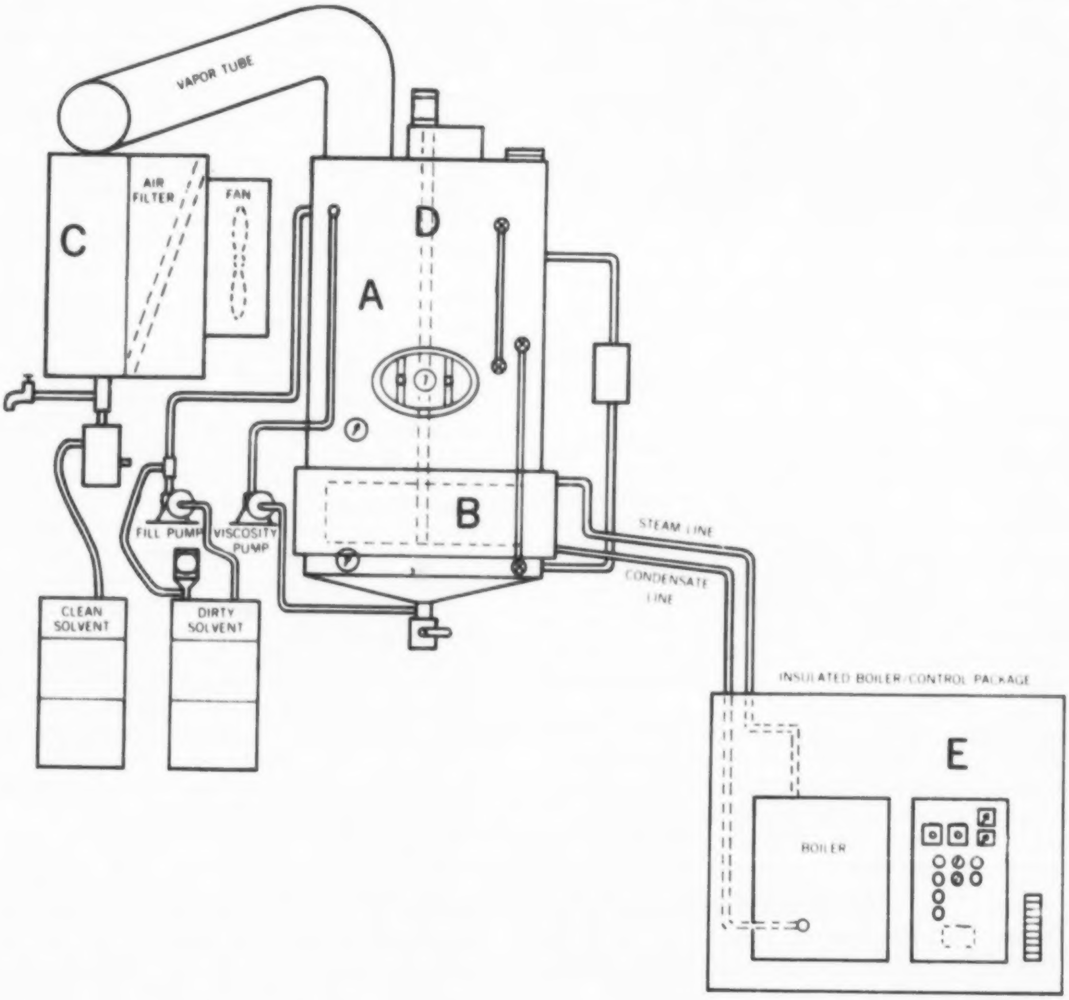

Figure 1—Flow Diagram, Standard Still.

will be approximately 100%, a one year payout! It is very common that many users have ROIs of 200-400%. One user in Indiana has been operating his still for 3 years at 28 gallons/hour, 24 hours/day, 5 days/week. He processes 14,300 gallons/month with a yield of 93%. Using a minimal cost of this ketone of $2.00+ per gallon, his savings currently amount to approximately 1/3 of a million dollars per year, for a low 5-figure investment.

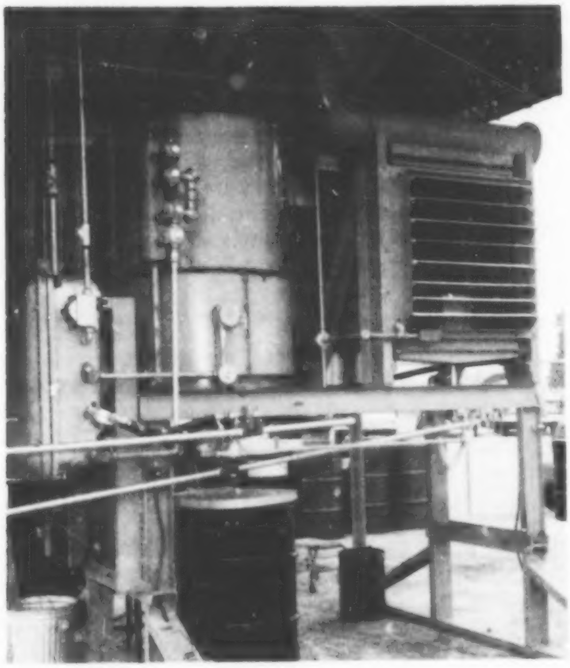

Fig. 2—Recovery Still.

Another example is a still at GTE-Sylvania in Tennessee. See Figure 2. This still is nearly 100% automatic, being fed from an underground tank and the clear recovered solvent flows by gravity to another underground tank—labor input is nominal. The engineer in charge is quoted as follows:

"Our still extends the life of our acetone tremendously. With the exception of losses through process evaporation and sludge collection, we are able to use the same acetone for a minimum of six cycles. This solvent life extensions has decreased our cost per gallon from $1.45 to about 30¢ which includes our cost of operating the reclaimer.

In addition to this bulk reclaiming operation, we are enjoying further savings by reclaiming thousands of gallons of drummed acetone and alcohol collected during prior years. By reclaiming we return it to the drum and use it over and over.

"The combination of savings, which in total exceed $50,000 a year, the peace of mind from virtual independence from outside solvent availability, and our compliance with tough new hazardous waste disposal standards makes in-house solvent reclaiming a great addition to our operation."

SOLVENT RECOVERY WITH STEAM/IN SITU (IN DRUM) DISTILLATION

(Nominal Rate: one drum/shift)

How it works:

This process works by distilling the solvents directly out of the drum to a condenser for collection. Leaving the material in its drum is a real advantage since many drums cannot be pumped out completely (in some cases, not at all). Further, if the goal is to remove *all* solvents (as in the case in this process), the final non-volatile material will be a rock or sand-like 'mess' - best left in a disposable drum rather than in processing equipment causing, perhaps, costly clean-up.

The distilling is done by a special method (patent pending) of steam injection safely into the contaminated liquid or sludge in the drum. As a result, the condensate is both water and solvent (in most cases the solvent is immiscible in water, therefore, easily separated. If the solvent is miscible with water—very few are—this process is not applicable).

The drum of material can, of course, be the viscous residue from the previously discussed (still) operation, or in the case of a very small usage, from the user's process. This is to say, if a company only has one drum per day or one drum per week, this process would be economical and recommended.

The operating sequence is as follows: The drum is placed inside a special insulated cabinet. The band steam heater (part of the cabinet) is closed around the drum. A very special (but inexpensive) steam sparger line is inserted into the drum through the smaller bung opening in the top of the drum and connected by a flexible line to the controlled steam line. The larger (2") bung opening is connected by a flexible line that goes to the condenser. By simple temperature control the following occurs: The liquid is heated to the boiling temperature by the steam jacket, so called "dry heat." This temperature is the azeotropic boiling point of the solvent-water mixture that will exist inside the drum (due to some water condensation in the drum). For example, if the solvent was toluene (normal boiling point of 231° F) the azeotropic boiling temperature is 185° F. It will always be less than the boiling point of water, 212° F - no matter what solvent is in the drum. This is a real advantage, allowing the recovery of even high boilers, 300-400° F range, with just steam.

When at this azeotropic boiling point, the steam to the sparger is activated and the steam enters the liquid in the drum by the special sparger. Two phenomena occur: (1) part of the steam strips the solvent into vapor which exits the drum; and (2) of critical importance, the steam, if properly sparged into the liquid, will cause heat transfer into the whole mass rather than just to localized areas of the sludge causing caking and slowing of the heat transference which would nullify the entire process.

This is the gist of this technology. To explain: The contaminated solvent will start, perhaps, as fluid and become thicker and thicker until it reaches an infinite viscosity (!), i.e. it ends up as a solid. Thus, one would ask how the heat is effectively transferred to this extremely thick material towards the end of the process. The answer is that the water, condensed due to earlier heat transfer (discussed above), is the heat transfer media to the final solid contamination. In a typical, properly operated situation, there will be about 10 gallons of water in the drum at the end of the solvent stripping.

The steam and solvent vapor enter a condenser, similar to the condenser on the still discussed earlier, and condenses. A simple two-layer separation tank removes the condensed water from the condensed liquid solvent.

At the end of the operation the temperature will rapidly rise from the boiling temperature up to 212° F, the boiling point of water, indicating there is no solvent

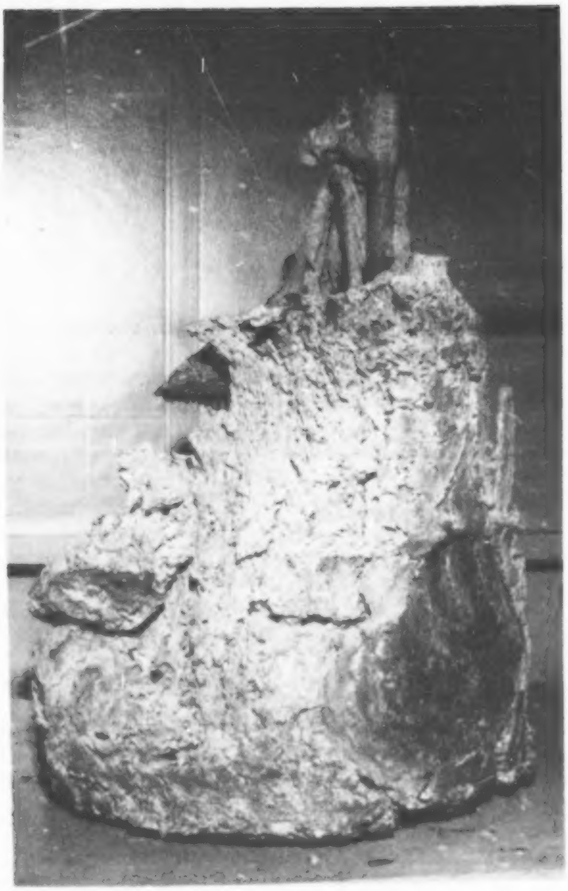

Fig. 3—Solid Residue.

left. At this point, the steam to the sparger stops. The dry heat (jacket) continues until the water is boiled away.

After this operation, the drum is removed from the cabinet. The top of the drum is cut off. The toxic, non-volatile contaminants, often looking like rocks or sand, that remain are pulled out of the drum with the *disposable* steam sparger. This solid material can be disposed of by safe, legal methods, usually directly to an approved landfill.

Figure 3 shows the solid residue from this process. This is a dramatic picture, in that it represents the solid, non-volatile toxic materials that originally (before both processes described herein) were contaminated with *about 800 gallons of solvent!* That is, the processes yielded about 770 gallons of pure solvents and this 'rock'; good from a hazardous wastes and an economic standpoint. The disposable sparger pipe can be seen sticking out of the top of this 'rock'. The bottom of the rock, you will note, conforms to the inside of a 55-gallon drum, i.e. the bottom of the rock is 22" in diameter (to give the reader a dimensional reference).

Economics:

The economics are very similar to the still discussed above. The return on investment (ROI) ranges from 75 to 300%. Investment is just at the 5-figure range.

Labor input required is essentially nominal since the operation is automatic once the drum is put into the unit.

CONCLUSION

The 1976 Resource Conservation and Recovery Act states:

> "(c) Materials - The Congress finds with respect to materials, that—
>
> "(1) millions of tons of recoverably material which could be used are needlessly buried each year;
>
> "(2) methods are available to separate usable materials from solid waste; and
>
> "(3) the recovery and conservation of such materials can reduce the dependence of the United States on foreign resources and reduce the deficit in its balance of payments."

We have revealed in this presentation high viscosity distillation processes that have the capability to recover materials just as Congress dictated above. Distillation is rarely thought of as a waste treatment process. But, in fact, it is one of the best, yielding recyclable materials (as solvents, discussed herein) or clean liquid condensates that can be incinerated without resultant toxic fly-ash-like solids in the effluent gas. Distillation energy cost is minimal, only about 2¢ to 3¢ per gallon, relative to the high value of the recovered material and/or the high value of avoiding hazardous solvents.

The specific processes discussed for industrial organics (solvents, etc.) in drum quantities allow economical recovery and, also, waste elimination for even the smallest company.

VOC Incineration and Heat Recovery - Systems and Economics

Roy M. Radanof*

INTRODUCTION

Volatile Organic Compounds (VOC) from metal finishing operations must be controlled to help preserve our nation's clean air standards. While many metal finishers have converted to formulas with reduced or no VOC, many others have chosen add-on incineration as a means of VOC control.

Two types of incinerators are available for air pollution control, thermal and catalytic units. Thermal incinerators consist of a volumetric enclosure through which solvent laden discharge air mixture from curing ovens passes. A fuel source, usually natural gas or No. 2 fuel oil, is used to raise the temperature of the air stream to 1200 to 1400° F. At this temperature, most of the VOC (solvent) is destroyed by oxidation. The final emissions contain CO_2, water vapor, N_2, air and traces of the original solvent.

The solvent destruction efficiency of thermal incinerators is dependent upon the retention time of the solvent at the control temperature, the control temperature itself, and the degree of turbulence within the incinerator. VOC destruction efficiencies of greater than 90 percent are common with these units.

Thermal incinerators are easily controlled and usually have built-in bypass dampers around the primary heat recovery unit to facilitate process variations.

Catalytic incinerators are similar to thermal incinerators, except that a catalyst has been added to enable the solvents to oxidize at a significantly lower temperature than in thermal units. Catalytic incinerators have a preheat section at the inlet in which fuel is added to raise the waste air temperature to the minimum required for the oxidation reaction to take place on the catalyst surface. As the solvents oxidize, additional heat is released, thus promoting the destruction of solvents. The final temperature achieved in the oxidation affects the destruction efficiency of the unit in addition to life of the catalyst. Catalytic incinerators can usually achieve the same destruction efficiencies as thermal units; however, they are more limited in their applications to process conditions.

The addition of either a thermal or catalytic incinerator for the destruction of VOC will usually accomplish the environmental objective of air pollution control; however, if proper engineering analyses of the total plant conditions are not conducted, the plant can be severely penalized with excessive operating fuel costs. On the other hand, a thorough and comprehensive analysis of the total plant can result, in many cases, in the incinerators being operated at no energy penalty or can even achieve a net energy savings for the plant as compared to energy requirements before the incinerator was installed.

This paper highlights fuel requirements, heat recovery options and economics of operating both types of incinerators. The energy benefits that are possible will provide economic incentives for plants to install incinerators as a means of achieving the environmental objective of air pollution control. The DOE Technology Applications Manual entitled, "The Coating Industry: Energy Savings with Volatile Organic Compound Emission Control," TID-28706, published in 1979, provides in-depth analyses of the concepts highlighted in this paper.

WHICH TO SELECT: THERMAL OR CATALYTIC INCINERATION

One of the most common questions asked when implementing an add-on incinerator is: "Which is better, thermal or catalytic?" Unfortunately, the answer is: "It depends on the site conditions."

The environmental objective is the same for each—to achieve a high solvent destruction efficiency that complies with regulatory standards. Without studying the overall plant conditions, the "best" choice cannot be determined. A brief review of the advantages and disadvantages of both types of systems will highlight some of the considerations.

ADVANTAGES OF THERMAL INCINERATION

Thermal incinerators can usually achieve solvent destruction efficiencies greater than 90 percent. Efficiencies as high as 97 to 98 percent are obtainable on newer units. Thermal incinerators can be used with a wide range of applications. Particulates and resins usually are destroyed with the solvents. Thermal incinerators are insensitive to solvent concentration variations. Because of their high operating temperatures, there is a high heat recovery potential. Thermal incinerators can operate with solvent concentrations up to 50 percent of the Lower Explosive Limit (LEL), providing the proper instrumentation and controls are employed to comply with the National Fire Protection Association codes and standards. Fuels consist of natural gas, oil, or propane.

DISADVANTAGES OF THERMAL INCINERATORS

Thermal incinerators have a potentially high operating cost primarily due to energy consumption. A large volumetric air flow rate is heated from temperatures typically at 200-300° F to 1200-1400° F. Without heat recovery, the exhaust gases carry away millions of Btu which are lost to the atmosphere. Since retention time is important for destruction efficiency, thermal incinerators are large, sometimes posing siting problems. There is no solvent recovery with thermal incinerators;

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however, the solvents usually contribute a substantial fuel value to the operation of the incinerator. The heat provided by the solvent during oxidation reduces the incinerator fuel requirement by an equivalent amount of heat. This is an important concept in estimating the energy requirements for incinerator operation.

ADVANTAGES OF CATALYTIC INCINERATION

Like thermal incinerators, catalytic incinerators can usually achieve the same solvent destruction efficiencies. Catalytic units can handle multisolvent mixtures, providing these mixtures were considered during the design and specification of the catalyst materials. Without considering heat recovery, catalytic incinerators have a significantly lower operating cost in terms of fuel expense than thermal incinerators. In the preheat section of a catalytic unit, waste air is heated from 200-300° F to 550-900° F. This temperature rise is lower than that required for a thermal unit performing the same duty.

The final exhaust temperatures from catalytic units usually range from 900 to 1200° F. This exhaust temperature has high heat recovery potentials for use elsewhere in the plant or for reducing the cost of incinerator operation as will be illustrated shortly. Retention time is not so important with catalytic units as with thermal units; therefore, the units are usually smaller than thermal units for equivalent air flows.

The temperatures referenced in the discussion so far are for a wide variety of applications. Many vendors have catalyst materials that operate effectively at temperatures significantly different from those referenced and can have equally significant effects on energy consumption. This is another factor for consideration in selecting the best type of incinerator for a site specific condition.

DISADVANTAGES OF CATALYTIC INCINERATORS

Catalysts are limited to the number of applications in processes since some waste air streams may contain catalyst poisons such as phosphorous, bismuth, lead, arsenic, antimony, mercury, iron oxide, tin, silicon and others. These poisons cause irreversible reduction of the catalyst activity at a rate dependent on concentration and temperature. Excessively high temperatures also will deactivate the catalyst in a shorter period than its normal life. While higher temperatures will provide greater destruction efficiency, catalyst life will be decreased and, consequently, maintenance costs will rise. Particulates and resins must periodically be cleaned from catalysts to reduce plugging and to maximize available surface area for reactivity. Like thermal incinerators, solvents are destroyed and are unavailable for recovery. Catalytic incinerators are more limited in fuel options than are thermal incinerators. Usually, natural gas is used as the fuel source. Oils containing sulfur can influence the catalyst activity by placing a reversible surface coating on the active area of the catalyst. Catalysts are expensive to replace. Some plants considering using catalytic incineration might have to precondition their waste air stream to prevent problems with the catalyst.

REDUCTIONS OF INCINERATOR FUEL CONSUMPTION

Several years ago, when energy was less expensive and more plentiful, heat recovery was not normally included with incinerators; and plants purchased equipment at minimum capital expenditure. Today, plants can justify additional capital outlays for reducing energy consumption by lowering air flows to increase solvent concentration, and by including heat recovery options.

LOWER AIR FLOW TO INCREASE SOLVENT CONCENTRATION

The NFPA, Code 86-A, "Ovens and Furnaces," describes conditions under which solvent concentrations must be kept below 25 percent of the LEL and those in which concentrations may approach 50 percent of the LEL. This paper addresses the conditions below 25 percent of the LEL since this is the area where the majority of the metal finishers presently operate.

The NFPA provides two methods of calculating the solvent concentration in terms of percent of the LEL. One method referred to as the "general method," is based on using 10,000 cubic feet of dilution air at 70° F for every gallon of solvent evaporated to achieve a solvent concentration of 25 percent of the LEL. This provides a convenient calculation for approximation, but it is usually conservative in specifying needed dilution air flows. Since the fuel input to the incinerator, as well as the oven, is determined by the energy required to heat the air flow rate to a specified temperature, any reduction in the air flow will lower the fuel requirement. This, then, becomes an objective for energy reduction and can be accomplished by following the second NFPA calculation method.

The second method allows the solvent concentration to be determined by actual consideration of the solvent composition and properties. It is more rigorous than the first method, but it usually results in less dilution air requirements.

For example, Figure 1 shows solvent removal rates at 25 percent of the LEL. If Methyl Ethyl Ketone (MEK) were evaporated at 60 gph, then 10,000 scfm of dilution air would be required using the "general method." If the actual LEL of MEK was considered, then the required dilution air would be approximately 45 percent lower than using the general method. The fuel effect of this air reduction will be seen shortly.

Typically, metal finishing operations are performed at solvent concentrations in the 7 to 10 percent of the LEL range with many falling as low as 1 to 2 percent of the LEL. If these solvent concentrations were increased to 20

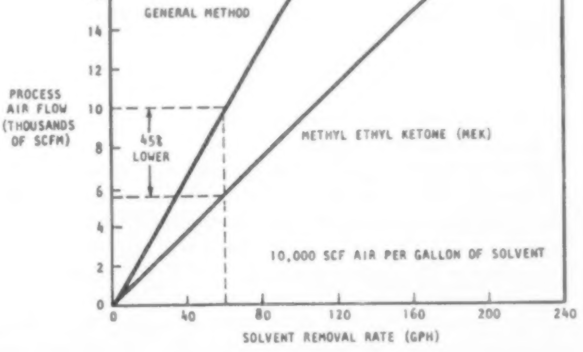

Fig. 1—Solvent removal rates at 25 percent of the LEL.

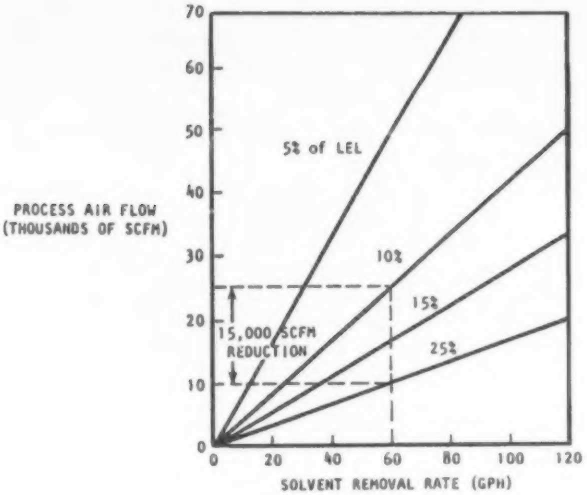

Fig. 2—Air flow requirements for solvent removal rates.

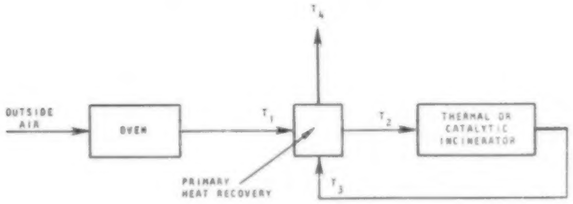

Fig. 3—Typical primary heat recovery.

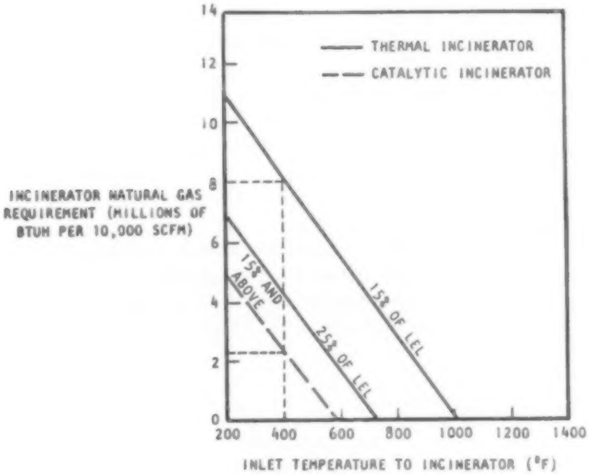

Fig. 4—Energy required for thermal and catalytic incineration without heat recovery.

to 25 percent, the reduced air heating loads would conserve considerable fuel.

For example, Figure 2 illustrates air flow requirements for different solvent removal rates. It is based on using the general method of 10,000 cubic feet of dilution air per gallon of solvent evaporated. An oven operating at 60 gph solvent removal rate and at a solvent concentration of 10 percent of the LEL can have its air flow reduced from 25,000 to 10,000 scfm by increasing its solvent concentration to 25 percent of the LEL. This results in 60 percent air flow reduction.

INCREASE INLET AIR TEMPERATURE TO INCINERATOR

In addition to lowering the dilution air flow, the inlet air temperature to the incinerator can be increased through primary heat recovery to reduce fuel requirements. Figure 3 illustrates a typical primary heat recovery application. The hot incinerator exhaust gases at temperature T_3 are recycled to a primary heat exchanger where they raise the oven waste air stream from temperature T_1 to T_2. The exhaust gases are finally released to the atmosphere at temperature T_4 or can be further used as a secondary heat source.

Figure 4 shows the combined effects of reduced air flows and increased incineration and/or inlet temperatures on fuel consumption for thermal and catalytic units. This figure is specific to the conditions shown below; however, it is illustrative for similar process conditions.

The basis for Figure 4 is given below:

1. Solvent is toluene (catalytic ignition temperature is 575° F with particular catalyst considered)
2. Natural gas HHV = 1100 Btu/scf
3. Thermal incinerator operating temperature = 1400° F
4. Catalytic incinerator exhaust temperature = 1000° F
5. HHV of toluene = 4484 Btu/scf
6. 95 percent destruction efficiency of toluene
7. LEL of toluene = 14,000 ppm
8. No heat losses
9. Waste stream air from oven exhaust used as combustion air in incinerator

First, the fuel requirements for thermal and catalytic units can be compared for the same given process conditions. For example, at an inlet temperature to a thermal incinerator of 400° F and with a solvent concentration of 15 percent of the LEL, the natural gas requirement is 8 million Btu/hr/10,000 scfm of process air flow. Under the same process conditions, if a catalytic incinerator were used, the natural gas requirement would be 2.3 million Btu/hr/10,000 scfm of process air. A 71 percent fuel reduction is experienced with the catalytic unit as compared to the thermal unit, both operating without heat recovery.

To illustrate the effects of reduced air flow, consider the thermal incinerator now operating at 15 percent of the LEL and with an inlet air temperature of 400° F. If the air flow were reduced to achieve 25 percent of the LEL, the natural gas requirement would decrease from 8 million to 4.4 million Btu/hr/10,000 scfm of process air flow. Combining the reduced air flow with primary heat recovery so that the new inlet air temperature to the thermal incinerator is 600° F, the natural gas requirement is further reduced to 1.5 million Btu/hr/10,000 scfm of process air flow. Thus, a process air flow of 20,000 scfm adjusted to the above conditions would require 3.0 million Btu/hr of natural gas [(20,000 scfm/10,000 scfm) × 1.5 million Btu/hr] to achieve a solvent destruction efficiency of 95 percent. The goal is to establish the highest possible solvent concentration allowed by NFPA standards and to achieve the maximum possible heat recovery to minimize incinerator fuel requirements

There are several important considerations to keep in mind. All VOC have an autoignition temperature where oxidation takes place. In recuperative type shell and tube heat exchangers, tube failure could occur if the solvent is allowed to reach its autoignition temperature inside the exchanger. It is, therefore, a good practice to limit the waste air preheating to a maximum temperature of 100° F below the solvent's autoignition temperature.

In regenerative type heat exchangers, such as stone beds and ceramic wheels, autoignition is not usually a problem, and higher preheat temperatures can be achieved.

Another consideration is that for every percent of the LEL of the solvent present, a temperature rise of approximately 27.5° F is experienced for 100 percent destruction efficiency of the solvent. All incinerators have a maximum design operating temperature which should not be exceeded; otherwise, equipment damage might occur. If this temperature were 1500° F, then care must be taken in sizing the primary heat recovery unit so that the preheat temperature, when combined with the temperature rise from the oxidation of the solvent, will not exceed 1500° F. For example, if the solvent concentration were 15 percent of the LEL and the preheat temperature were 800° F, then the resulting operating temperature would be approximately 1488° F which is below the maximum design temperature.

The same considerations apply to catalytic units. Figure 5 shows the combined effect of inlet and outlet temperatures of catalysts for 90 percent solvent destruction efficiency. This figure is for one particular solvent/catalyst combination; however, it is representative for other combinations if the temperature were adjusted.

The upper curve is the exhaust temperature from the catalyst. From 0 to 15 percent of the LEL, the curve is flat at 1000° F. This is the minimum exhaust temperature that will result in 90 percent destruction for the particular solvent.

The lower curve represents the required inlet temperature to the catalyst at the given solvent conditions that will result in the required outlet temperature. For example, in the solvent concentration range of 0 to 15 percent of the LEL, it will be necessary to add supplemental fuel to the incinerator preheat section or to utilize primary heat recovery to achieve the minimum inlet temperature shown. If the solvent concentration is at 10 percent of the LEL, then the waste air stream will have to be heated to about 700° F before entering the catalyst. The fuel value of the solvent will result in the final temperature rise to the required 1000° F.

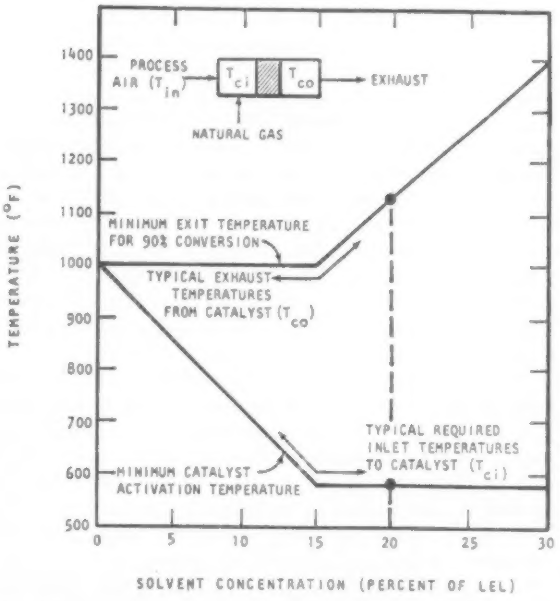

Fig. 5—Catalyst temperatures at 90 percent solvent destruction efficiency.

Above 15 percent of the LEL, the effect is different. Since the catalyst has a minimum reactivity temperature that must be achieved to start the oxidation process, it is not possible to enter the catalyst below this activation temperature. In Figure 5, the reactivity temperature is 575° F. If the solvent concentration is greater than 15 percent of the LEL, then the resulting exhaust temperature will exceed the 1000° F and will seek a level depending on the exact amount of solvent present. For example, if the solvent concentration were at 20 percent of the LEL, then the minimum reactivity temperature would be achieved either by primary heat recovery or supplemental fuel. The solvent's heating value and quantity would increase the exhaust temperature to about 1130° F. At this temperature, the destruction efficiency is improved; however, it is a more severe condition for the catalyst.

In quantifying the amount of primary heat recovery to be used, the most common practice is to use the term "percent heat recovery." Percent heat recovery is a ratio of the amount of heat recovered to the amount of heat that is available for recovery. Commonly, it is expressed as a temperature ratio as shown in Figure 6, since the gas flows to and from the incinerator are assumed to be equal through the heat exchanger if external combustion air is not added to the incinerator. There is a more rigorous definition of percent heat recovery based on enthalpies; however, the temperature ratio will be sufficient for most purposes.

Figure 7, shows the limits of primary heat recovery for thermal incinerators. A similar figure can be constructed for catalytic incinerators. Figure 7, is based on the following conditions:

1. Incinerator exhaust temperature = 1400° F
2. Solvent is toluene having HHV = 4484 Btu/scf and LEL = 14,000 ppm
3. Shell and tube heat exchanger limit includes a 100° F safety factor below autoignition temperature of toluene

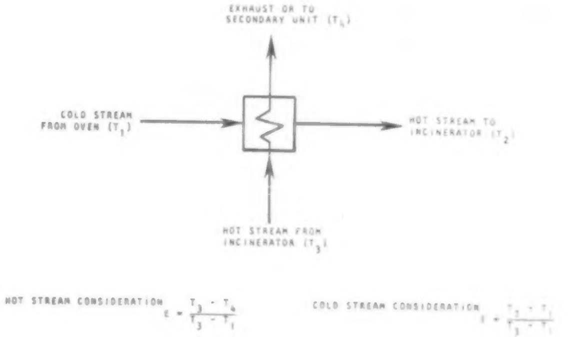
EXHAUST OR TO SECONDARY UNIT (T_4)
COLD STREAM FROM OVEN (T_1)
HOT STREAM TO INCINERATOR (T_2)
HOT STREAM FROM INCINERATOR (T_3)
HOT STREAM CONSIDERATION $E = \frac{T_3 - T_4}{T_3 - T_1}$
COLD STREAM CONSIDERATION $E = \frac{T_2 - T_1}{T_3 - T_1}$

Fig. 6—Percent Heat Recovery.

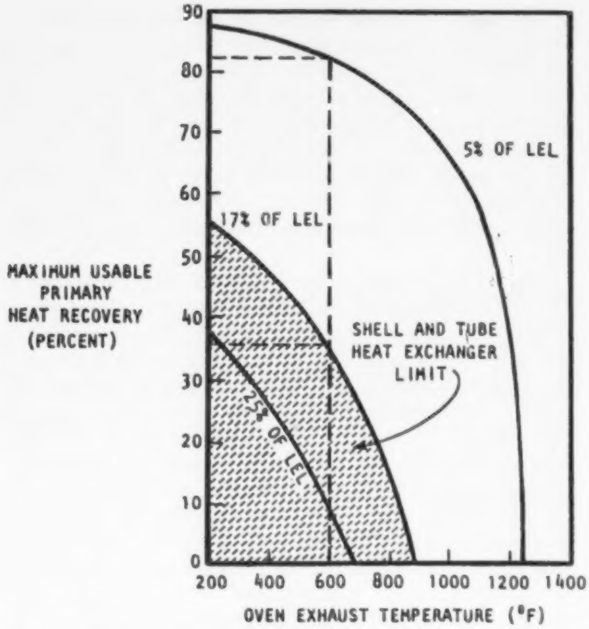

Fig. 7—Limits of Primary Heat Recovery for Thermal Incinerators.

4. 100 percent destruction efficiency of toluene
5. Autoignition temperature of toluene = 997° F
6. No heat losses
7. Waste stream air from oven exhaust used as combustion air in incinerator

So as not to encounter autoignition damage in the primary heat exchanger, shell and tube units should be applied only to the conditions represented by the shaded area. Regenerative units not susceptible to autoignition damage can be operated in the shaded or unshaded areas.

For example, an oven that exhausts gases at 600° F and at five percent of the LEL for toluene will allow a maximum usable primary heat recovery of 82 percent for those heat exchangers not susceptible to autoignition damage. Because the temperature limitation is 897° F for shell and tube heat exchangers with toluene, the maximum heat recovery achievable at this solvent concentration would be only 36 percent to prevent autoignition damage. At five percent of the LEL toluene concentration and with maximum usable heat recovery for shell and tube exchangers, the gases would leave the exchanger at 897° F (as read at the intersection of the limit curve with the horizontal axis), and auxiliary fuel would be required to raise the temperature from 897° F to 1250° F (intersection of 5 percent of LEL curve with horizontal axis). The fuel value of the toluene would provide the heat necessary in going from 1250° F to 1400° F. If a heat exchanger could operate with 82 percent heat recovery, the gases would exit at approximately 1250° F and auxiliary fuel flow would be negligible.

It is important when purchasing a primary heat recovery unit to know that it is possible to use the level of heat that the equipment is capable of recovering.

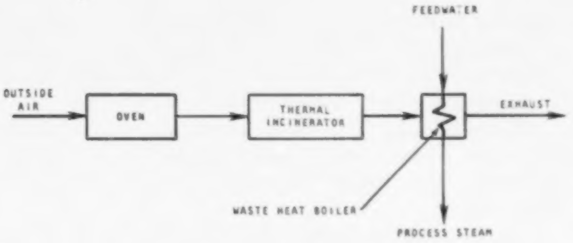

Fig. 8—Secondary heat recovery with a waste heat boiler.

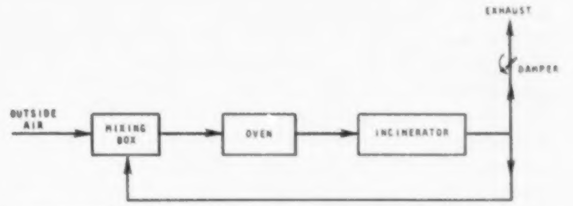

Fig. 9—Secondary heat recovery with direct gas recirculation.

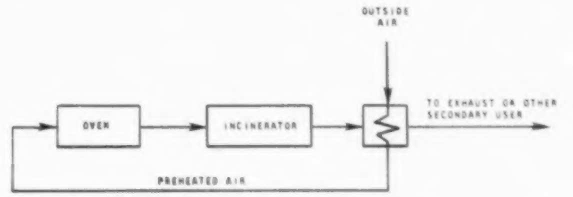

Fig. 10—Secondary heat recovery with indirect heating.

SECONDARY HEAT RECOVERY

Secondary heat recovery is the utilization of the heat in the incinerator exhaust gases for any purpose other than preheating the inlet air to the incinerator (primary heat recovery). Figures 8, 9, and 10 illustrate three common applications of secondary heat recovery.

Figure 8 shows a waste heat boiler that is driven by the hot exhaust gases from a thermal incinerator. Low pressure process steam is generated for utilization elsewhere in the plant for process or building heating.

Figure 11 is based on generating 40 psig saturated steam and shows steam capacities and fuel savings using waste heat boilers. The exhaust from the waste heat boiler is set at 450° F and an 85 percent boiler efficiency is assumed. Feedwater is set at 200° F, and natural gas having a HHV of 1100 Btu/scf is used as the energy source for comparative fuel savings to a package boiler.

For example, a waste heat boiler operating with an inlet temperature of 1000° F with 10,000 scfm and an exhaust temperature of 450° F will generate 6,400 pounds/hour of 40 psig saturated steam. This will save an equivalent of 8 million Btu/hr of natural gas in a package boiler to generate the same quantity of steam.

Figure 9 shows the direct mixing of recirculated exhaust gases with fresh outside air going to the oven. The preheating of the oven supply air significantly reduces the fuel requirement for the oven. Care should be used in operating this type of system to assure that the solvent concentration in the oven does not creep up due to a malfunction of the incinerator in destroying the solvents.

The indirect heating of oven supply air, shown in Figure 10, prevents recirculating any solvent vapors by

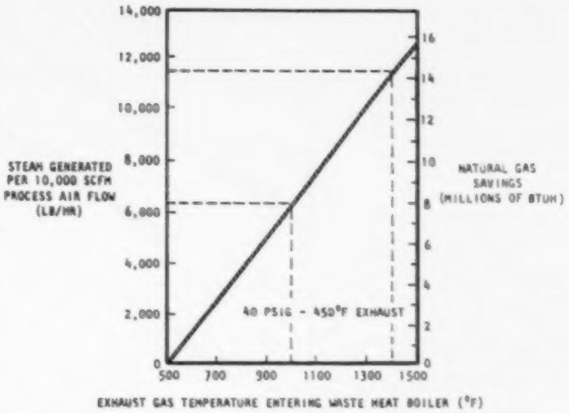

Fig. 11—Steam capacities and fuel savings of waste heat boilers.

employing an air-to-air heat exchanger with separate air paths.

A "net energy savings" for the plant is only possible using secondary heat recovery. A net energy savings is accomplished by putting the heat released from the oxidation of the solvents to work. Many solvents have heating values that are 4 to 5 times greater than those of natural gas. If suitable heat sinks are available to utilize this heat, then the economics of the heat recovery options should be explored to determine the value of investments.

Figure 12 illustrates both the energy required and recoverable using thermal incinerators with secondary heat recovery. A similar figure can be developed for catalytic units. Figure 12 is based on the following assumptions:

1. Thermal incinerator operating at 1400° F
2. No primary heat recovery - secondary recovery only with waste heat boiler
3. 85 percent boiler efficiency assumed
4. Solvent is toluene (HHV = 4484 Btu/scf)
5. Fuel is natural gas (HHV = 1100 Btu/scf)
6. Waste stream air from oven exhaust used as combustion air in incinerator

For example, if the inlet temperature to a thermal incinerator were 500° F, the natural gas requirement of the incinerator is 6.6 million Btu/hr/10,000 scfm process air flow for a solvent concentration of 15 percent of the LEL of toluene (See point W). At a waste heat boiler exhaust temperature of 500° F, 10.6 million Btu/hr/10,000 scfm process air flow (point X) will be transferred for the production of steam. This amount of energy being transferred would save 12.2 million Btu/hr/10,000 scfm process air flow of fuel (point Y). The plant achieves a net energy savings of 5.6 million Btu/hr/10,000 scfm process air flow (12.2 - 6.6 million Btu/hr) if a use for 10.6 million Btu/hr/10,000 scfm process air flow could be found. The waste heat boiler would save 6.6 million Btu/hr10,000 scfm process air flow (the same energy as consumed in the incinerator) if the secondary heat recovery unit exhausted at 920° F (point Z). A catalytic unit, with a secondary heat recovery unit exhausting at 500° F would recover 5.8 million Btu/hr/10,000 scfm process air flow as compared to 10.6 million Btu/hr/10,000 scfm process air fuel requirements to operate the units, the net energy savings are nearly equivalent. The thermal unit must have a larger heat sink to achieve the same energy savings.

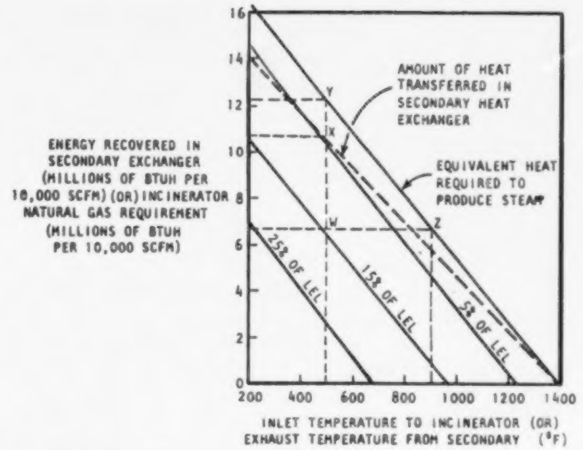

Fig. 12—Energy required/recoverable with thermal incinerators using secondary heat recovery.

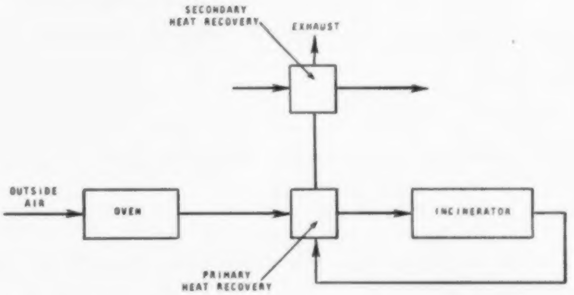

Fig. 13—Thermal incinerator with primary and secondary heat recovery.

Primary and secondary heat recovery can be used separately or together as shown in Figure 13.

The energy savings potentials of secondary heat recovery depend on three factors:

- **Availability of heat sinks that can effectively use the energy from the exhaust of the incinerator**
- Primary heat recovery applications and requirements
- Economics of heat recovery options

The economics of heat recovery options will be the criteria for determining whether or not primary heat recovery should be incorporated. If a plant could use the available energy from the incinerator exhaust gases more effectively with a secondary heat recovery unit, the need for primary heat recovery would be eliminated. The energy savings are still achieved because the energy supplied to the incinerator is replacing the energy previously used for the secondary recovery applications.

The quantity of energy available for secondary heat recovery from catalytic and thermal incinerators depends on the incinerator exhaust temperature and flow rate as was illustrated in Figure 12.

ECONOMICS

The operating costs of catalytic and thermal incinerators are greatly affected by heat recovery options and the solvent concentrations in the process air streams. Figure 14 illustrates approximate annual costs or profits for operating a thermal incinerator. A similar figure can be constructed for catalytic units. Figure 14 is based on the following assumptions:

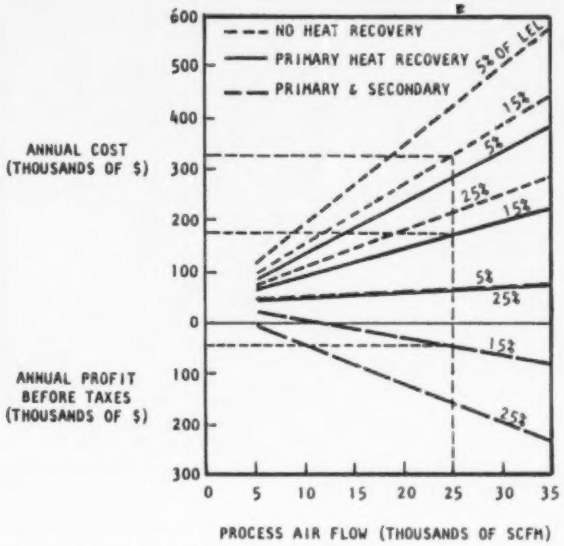

Fig. 14—Approximate annual cost/profit for thermal incineration.

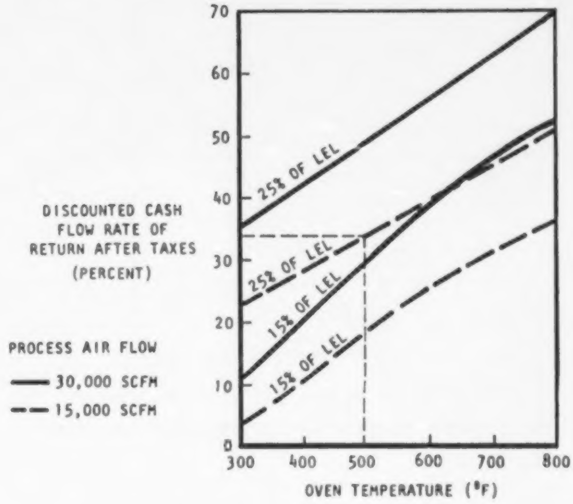

Fig. 15—Economics for thermal incinerators using maximum primary and secondary heat recovery.

1. Profits are calculated before taxes
2. Oven exhausts at 300° F
3. Solvent is toluene
4. 35 percent primary heat recovery
5. Secondary heat recovery with waste heat boiler exhausting at 450° F
6. Incinerator temperature = 1400° F
7. Operating time = 6000 hrs/yr
8. Natural gas cost = $2.00/million Btu
9. Operating labor = $8.00/hr
10. Supervision = $10.00/hr (50 percent of operating cost)
11. Maintenance = 6 percent of total investment
12. General plant overhead = 0.58 (operating labor + supervision + maintenance + labor salaries*)
*37 percent of maintenance costs
13. Depreciation: 10 yr straight line
14. Taxes and insurance: 2 percent of total investment
15. Additional labor requirements: operating labor assumed to increase 1/2 hour per shift per installation (avg. expense $2920/yr and/or $8/hr)

For example, an oven exhausts 25,000 scfm of air at 300° F and 15 percent of the LEL for toluene. The annual cost of operation for a thermal incinerator without heat recovery is $320,000. If a 35 percent primary heat recovery unit were added, the annual cost would reduce to $160,000. In addition to the primary heat recovery unit, if a waste heat boiler were installed, the plant operation would result in an annual profit before taxes of $50,000 due to the net fuel savings. As compared to a thermal incinerator without heat recovery, a thermal incinerator with both primary heat recovery and a waste heat boiler would provide an annual savings of $370,000.

Figure 15 illustrates the economics of using thermal incinerators with maximum primary and secondary heat recovery. Discounted Cash Flow (DCF) rates of return after taxes can be determined for various oven exhaust temperatures, process air flows and solvent concentrations.

Figure 15 is based on the following assumptions:
1. Toluene is solvent
2. Assumed shell and tube type primary heat exchanger
3. Secondary heat recovery with waste heat boiler
4. Incinerator temperature = 1400° F
5. Operating time = 6000 hrs/yr
6. Natural gas cost = $2.00/million Btu
7. Operating labor, supervision, maintenance, overhead, taxes and insurance, and depreciation are the same as for Figure 14.

For example, an oven exhausts 15,000 scfm of air at 500° F and at 25 percent of the LEL for toluene. If a thermal incinerator package which includes a shell and tube heat exchanger for maximum usable primary heat recovery and a secondary waste heat boiler were installed, the DCF rate of return on the investment would be approximately 34 percent.

Table I provides a comparison of thermal and catalytic incinerators using heat recovery for an oven operating with 15,000 scfm, 15 percent of the LEL, and at 300° F exhaust temperature. With no heat recovery, the fuel requirement for a thermal unit is about three times greater than for the catalytic unit. With maximum primary heat recovery (recuperative type), the catalytic unit can be operated at negligible fuel flow and the thermal unit still requires about 2.2 million Btu/hr. If a waste heat boiler were added to each unit, the potential net annual fuel savings are essentially the same, $68,000. However, for this savings to be achieved for the thermal unit, a use for 6,300 lb/hr of steam must be found as compared to only 4,500 lb/hr for a catalytic incinerator.

SUMMARY

This paper highlighted the similarities and differences of operating thermal and catalytic incinerators as a means of VOC air pollution control from metal finishing operations. Without heat recovery options, fuel costs of both types of incinerators could be a great penalty to the plant. With proper applications of primary and

TABLE I
THERMAL AND CATALYTIC INCINERATORS USING HEAT RECOVERY

Conditions: *300°* 15% of LEL 15,000 scfm
Natural Gas Fuel Cost $2 per million Btu's
Fuel rates stated in millions of Btu's per hour

	Catalytic	*Thermal*
Incinerator fuel rate No heat recovery	5.1	14.3
Fuel rate, maximum Primary heat recovery (Recuperative)	0	2.2
Steam generated in waste heat boiler, lb/hr	4,500	6,300
Net annual fuel savings with heat recovery	$67,500	$68,400

secondary heat recovery and with optimization of solvent concentrations in process air flows from the oven, energy consumption can be minimized and sometimes result in a net energy savings to the plant. Capital investments for heat recovery equipment can usually be recovered in a short time at today's energy costs.

It is important to realize that each plant site is unique in its operation and should have its processes analyzed before implementing an incinerator/heat recovery package. There are many good packages offered by the vendors; however, each system cannot be universally applied to all applications with the same expected performance and economic returns on investments. A review of the literature sited under "References" will provide many details and in-dept analyses for implementing an incinerator add-on program.

REFERENCES

DOE Technology Applications Manual, "The Coating Industry: Energy Savings with Volaltile Organic Compound Emission Control," TID 28706, 1979.

DOE Technical Briefing Report, "Oven Curing: Energy Conservation and Emission Control in Coil Coating," TID-28705, 1978.

"Environmental And Energy Benefits Achievable By Computer Control of Air Flow In Bake Ovens"

Matt Heuertz*

INTRODUCTION

Methods of reducing fuel consumption in curing system VOC emission control incinerators were discussed in the previous paper, "VOC Incineration and Heat Recovery Systems and Economics" by Roy M. Radanof, CENTEC Corporation. The two methods established for reducing incinerator fuel consumption were reducing air flows to increase solvent concentration and installing heat recovery options to increase the inlet air temperature to the incinerator. These methods similarly apply to curing ovens, although for curing ovens additional methods exist for reducing oven fuel consumption. Fuel usage in curing ovens is a function of dilution air flow, operating temperature, product and conveyor work load, and system losses. Since the product and conveyor work load must be a constant or increasing energy factor, only a change in material of construction or product and conveyor specific heats can reduce fuel usage. These savings will be insignificant compared to the saving potentials of the other usage functional variables.

Oven fuel usage reduction will result from:

1. A reduction in oven dilution air flow.
2. A reduction in curing oven operating temperature requirements.
3. Installation of secondary heat recovery.
4. Installation of oven zone incineration.
5. Initiation of a general maintenance program.

This paper will discuss the status of the Chemical Coaters Association Project, which involves the evaluation and demonstration of the environmental and energy benefits achievable by computer control of the dilution air flows in curing ovens. Substantial energy savings can result from a reduction of curing oven dilution air flows by installing a micro-computer, LEL controller system; in addition to the operating energy savings in ovens and VOC emission control equipment and a potential reduction in VOC emission control investment costs, the curing operation utilizing a micro-computer, LEL controller should be safer to operate.

CHEMICAL COATERS ASSOCIATION PROJECT

On September 28, 1979, the Chemical Coaters Association signed a cooperative agreement with the Environment Protection Agency on a program that will include an evaluation and demonstration of the environmental and energy benefits achievable by computer control of the air flow in bake ovens.

This multiple-phase project will cost over $700,000 with the bulk of the funds provided by the EPA and the Department of Energy, and the remainder cost-shared by the CCA and the company whose paint line will be used to demonstrate the control system.

The goal of the research program is to develop a control system that should maintain solvent concentrations in existing bake ovens at levels approaching 50 percent of the LEL (lower explosive limit). The system will be designed to provide consistent optimum energy utilization for variations in both paint formulations and the products being coated. Fuel savings should be experienced in both the bake ovens and incinerators or afterburners. The final design will comply with the National Fire Protection Association codes and standards.

Much of the engineering and technical support efforts for the project will be handled by CENTEC Corporation of Fort Lauderdale, Florida, under a sub-contract with the Chemical Coaters Association.

Charles Darvin, EPA project officer, and John Rossmeissl, DOE project officer, will provide guidance and will review the progress of the program whose expected completion date is October, 1981.

The CCA project consists of the following four work tasks:

Task 1—"Potentials for Improved Control Technologies"

At least 50 user members of CCA were contacted and asked to provide information on their paint bake ovens. Data required included such information as: oven capacity, types of coatings cured, fuel consumption, and a flow diagram of their plant with air pollution control equipment, if installed.

The information provided by the 50 plants will be used as input to a computer model developed by CENTEC which will determine the energy and environmental costs/benefits for curing ovens, incinerators and heat recovery devices by implementing a computer-controlled oven air system. The computer model is quite flexible and

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will handle nearly all known plant configurations using continuous curing ovens.

After compiling this background information, ten of these plants will be selected for personal visits by CENTEC engineers for further survey work.

A conceptual computer-controlled oven air system will be designed and a formal risk analysis will verify that the system is as safe or safer than present systems operating at solvent levels below 25 percent of the LEL with no solvent monitoring/control system.

An engineering report will be prepared that will show the projected energy and environmental benefits of a single plant installation and the benefits of an industry-wide application of the computer-controlled oven air technology.

Task II—"Site Selection and System Design"

The site selection for the start-up and operation of the prototype system will be made by the project team as a result of the findings from Task I.

The selection of the demonstration plant site will be made on the basis of its similarity of operation with other plants to assure widespread applicability of the control system in the industry. Detailed cost estimates for the hardware and installation costs will be completed; the demonstration plant must cost share the purchase and installation of the control system. Estimates of performance, operation costs and process economics for other coating plants will be defined. The software/hardware package for the micro-computer control system will be designed. A project report will be prepared that will summarize the results of Tasks I and II.

Task III—"Installation and Start-up"

Accurate documentation for the operating cost and performance of the oven at the demonstration site will be made prior to installation and start-up of the control system. The demonstration site will install the computer control system with technical assistance from the project team. The necessary preparations for start-up will be concluded. Once the control system is put into operation, and after confirmation of the control capability, the unit will be lined-out to confirm the system's performance. Documentation of all costs will be stated for comparison with projections and with the oven's original operation prior to installation of the control system.

Task IV—"Evaluation of Demonstration and Dissemination of Results"

The energy consumption and environmental efficiencies and long term reliability of the system will be monitored. Energy savings and environmental benefits will be documented by the project team with the assistance of the plant's staff. A project report will be completed during the later stages of Task IV. The report will describe technical and economic performance of the system and its potential applicability for the general coating industry. The report will provide necessary information for implementation by other plants. The Chemical Coaters Association is planning to conduct seminars and provide an applications manual to transfer the results of this program to the coating industry.

POTENTIAL SAVINGS FOR AIR FLOW REDUCTION

Figures 1, 2 and 3 show the potential energy cost savings for a given curing oven operation. The oven operating conditions initially were as follows:

1. Solvent concentration of 10 percent of the LEL.
2. Solvent removal rate of 50 GPH.
3. Oven exhaust temperature of 350° F.
4. Fuel cost of $2.50 per million Btu's.

By installing LEL monitor/control, which permits a solvent concentration of 50 percent of the LEL, the dilution air flow can be reduced 80 percent from 17,700 scfm to 3600 scfm as shown in Figure 1.

Figure 2 shows the energy requirements for heating

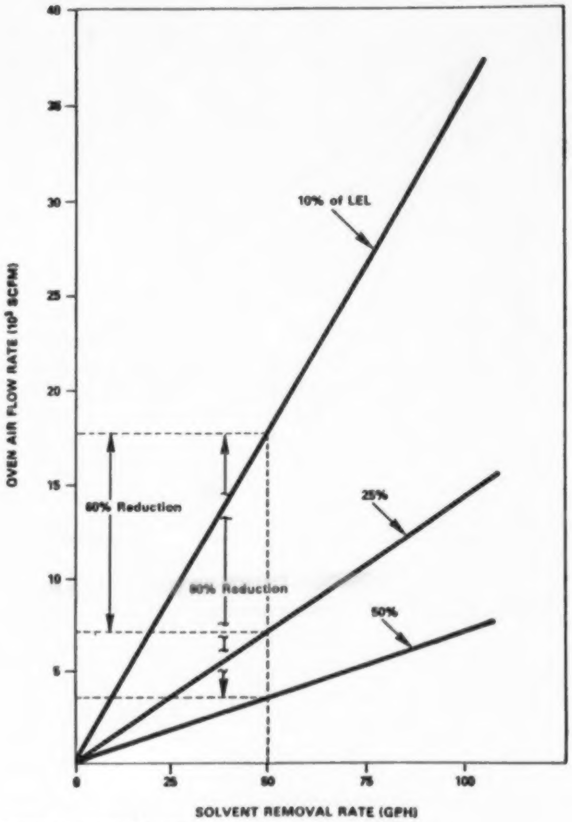

Figure 1—Oven Air Requirements for Solvent Dilution.

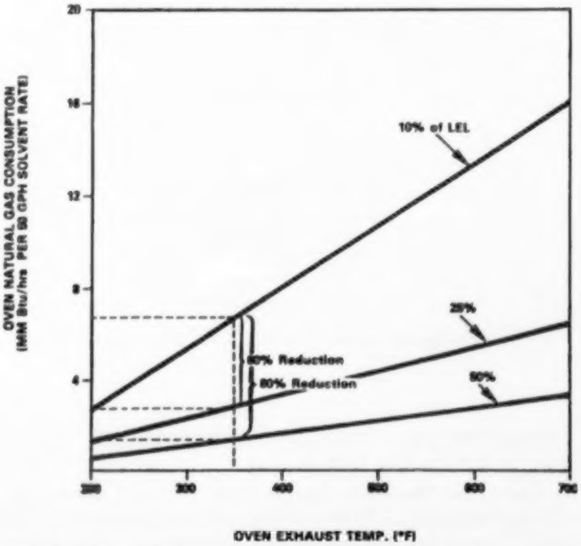

Figure 2—Energy Requirements for Oven Air Heating.

these dilution air flows. At ten percent of the LEL, the energy required for heating 17,700 scfm to 350° F is 6.8 MM Btu/hr. At 50 percent of the LEL, the energy required is 1.2 MM Btu/hr. The energy cost savings attributable to this energy reduction is $81,000 as shown in Figure 3. As fuel costs increase, the annual cost savings potential also increase for dilution air flow reduction.

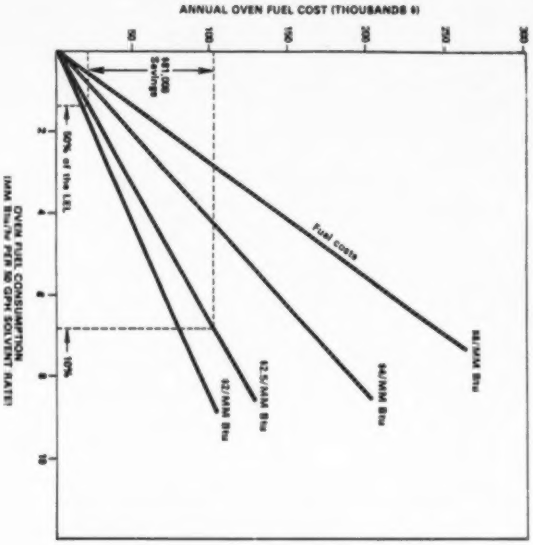

Figure 3—Energy Cost for Oven Air Heating.

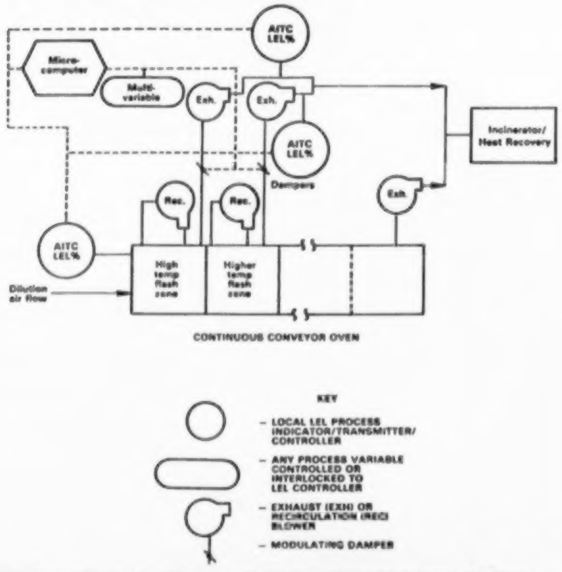
AITC LEL%
Micro-computer
Multi-variable
Exh.
Exh.
AITC LEL%
Incinerator/ Heat Recovery
Dampers
Rec.
Rec.
Exh.
AITC LEL%
High temp flash zone
Higher temp flash zone
Dilution air flow
CONTINUOUS CONVEYOR OVEN
KEY
– LOCAL LEL PROCESS INDICATOR/TRANSMITTER/ CONTROLLER
– ANY PROCESS VARIABLE CONTROLLED OR INTERLOCKED TO LEL CONTROLLER
– EXHAUST (EXH) OR RECIRCULATION (REC) BLOWER
– MODULATING DAMPER

Figure 4—Conceptual Design - Computer Controlled Oven Air Flow.

CONCEPTUAL DESIGN—COMPUTER CONTROLLED OVEN AIR FLOW

To realize this oven fuel savings, Figure 4 shows the conceptual design of the micro-computer controller. The system basis for this design is a continuous, multi-zone, conveyor oven. The solvent concentration in terms of percent of the LEL would be monitored for:

1. The inlet to the high temperature flash zone.
2. The exhaust from the high temperature flash zone.
3. The exhaust from the higher temperature flash zone.

The reasoning for these sensor locations is that the majority of solvent removal will occur in the initial high temperature flash zone under normal system operation. If a system upset occurs, i.e. the product is over sprayed, and the solvent removal capacity of the first zone is not adequate to handle this additional solvent, then this solvent will be vaporized as the product enters the next higher temperature zone. Since solvent concentration is uniform in each zone due to the typically large air recirculation rates, monitoring the solvent concentration in the higer temperature flash zone exhaust will be representative of the entire zone solvent concentration. As the design becomes increasingly site specific, the actual number of local LEL percent analyzer/indicator/transmitter/controllers could be reduced from three to ideally one, if the system layout will allow for multi-point sampling utilizing one analyzer. The LEL analyzer in this case should not be remotely located, since sample line run lengths must be minimized to reduce the chances of solvent condensation and pluggage due to resin particulates.

The LEL analyzer will primarily control air exhaust rates by modulating inlet vortex, exhaust, blower dampers. The LEL analyzer will be capable of automatic self-checking with alarm warning for high LEL or analyzer malfunction. If the analyzer malfunctions, the auto-dampers will be fully opened to maintain production. In addition to the alarm warning for high LEL, the system can control or interlock with any process variable to stop the coating, stop the conveyor or shutdown the combustion system.

The order of magnitude installed equipment cost and annual operating cost for the micro-computer control system are $120,000 to $150,000 and $15,000, respectively. The discounted cash flow rate of return after taxes and payback on investment is shown in Figure 5 for various annual fuel cost savings. For an oven operating at 350° F and a solvent removal rate of 50 GPH with a fuel cost of $2.50 per million Btu's, an annual fuel cost savings of $81,000 would be realized if the system dilution air flow rate was reduced to result in an increase in solvent

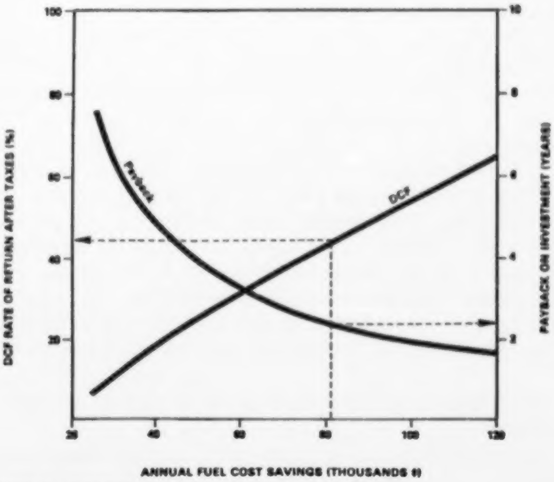

Figure 5—Economics of Oven Computer Control.

concentration from 10 percent to 50 percent of the LEL. This savings of $81,000 annually would result in a DCF rate of return after taxes of 44 percent and a payback on investment of 2.4 years. For ovens operating at higher solvent removal rates and higher temperature, the potential savings for LEL micro-computer control would be higher and, therefore, the DCF rate of return and payback would be even more attractive, since investment cost for LEL micro-computer control is essentially constant for varying system air flows, solvent removal rates, and operating temperatures.

COMPUTER MODEL FOR OVEN/INCINERATOR ENERGY ANALYSIS

The Oven/Incinerator Design Model determines the fuel consumption and fuel costs associated with continuous curing ovens and with incinerators used for volatile organic compound (VOC) air emission control. Fuel savings attributable to primary and secondary heat recovery schemes are also computed.

Energy utilization optimization can be determined by increasing the solvent concentration in the oven to levels approaching 50 percent of the LEL. Where existing incinerators may limit solvent concentrations to levels lower than 50 percent of the LEL, optimized fuel consumption also can be determined.

The model has a built-in file on solvent properties so that all calculations are based on actual constituents rather than average values. Solvent destruction efficiency is factored into fuel flow computations. Spray booths or other solvent laden air sources may be mixed with oven air exhaust as input to an incinerator. Both catalytic and thermal incinerators can be evaluated considering internal and external combustion air sources and different fuel sources. Zone oven incinerators also can be evaluated.

The fuel costs determined by this model may be used as input to CENTEC's economics model for determining discounted cash flow rates of return, returns on investments, and paybacks for capital investments.

Accurate calculations that normally would require several mandays of effort now can be performed in several minutes using these models. The accuracy and flexibility of this model will be demonstrated at the EPA exhibit booth by providing a free analysis for your curing operation.

This model was utilized to develop the following case studies.

CASE STUDY EXAMPLES

Two case studies are presented in Figure 6 and 7, which show the fuel costs, operating costs, investment costs and economics of LEL micro-computer control heat recovery and VOC emission control.

Case I—Typical Coating Line

This case involves an existing curing oven operating at 10 percent of the LEL, 20,000 scfm of dilution air flow, 350° F operating temperature, with a product/conveyor work load of 42,000 pounds per hour. The annual fuel costs for these existing oven operating conditions, assuming a fuel cost of $2.70 per million Btu's, are determined to be $161,000. The addition of LEL micro-computer control increasing the solvent concentration to 50 percent of the LEL reduces the annual fuel cost to $84,200 for a savings of $76,800. This was accomplished by an investment of about $120,000 for the LEL control system. This results in a return on investment of 41 percent and payback of 2.6 years, which includes the additional incremented controller operating cost of $15,100 annually.

If VOC emission controls are required for this curing operation, thermal and/or catalytic incinerators or carbon adsorption should be considered. Since the oven operating temperature is 350° F, carbon adsorption can be ruled out.

Thermal incineration was selected, since the coating resin potentially could poison the catalyst in a catalytic system. Since the LEL control was installed, the investment cost for adding thermal incineration will be lower, because the air flow rates were reduced. At the lower air flow rates, the total installed investment cost for

FIGURE 6
CASE I - TYPICAL COATING LINE

	Annual Syst. Costs, $					
Configuration	*Fuel Costs*	*Incremental Operating Costs*	*Incremental Annual Fuel Savings, $*	*Total Installed Investment Cost, $*	*ROI %*	*Payback, Years*
Existing oven (10% of LEL)	161,000	—		—	—	—
Controlled oven (50% of LEL)	84,200	15,100	76,800	120,000	41	2.6
Add thermal incin. to controlled oven	100,000	18,800	-0-	126,500	-0-	-0-
Add 60% recirc. to controlled oven from incin.	45,000	4,000	55,000	50,000	86	1.4
(or)						
Add waste heat boiler (5,300 lb/hr stm 40 psig)	100,000	17,700	*72,400	40,300	115	1.1

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*Fuel savings in steam plant.

FIGURE 7
CASE II - ACTUAL COATING LINE

Annual Syst. Costs, $

Configuration	*Fuel Costs*	*Incremental Operating Costs*	*Incremental Annual Fuel Savings, $*	*Total Installed Investment Cost, $*	*ROI %*	*Payback Years*
Existing oven, (2% of LEL)	71,000	—	—	—	—	—
(Controlled oven, 35% of LEL)	(48,300)	(15,100)	(22,800)	(120,000)	(2)	(8.7)
Add Cat. Incin. To Exist. Oven	149,200	34,500	-0-	172,500	-0-	-0-
(To Controlled Oven)	(74,800)					
Add Primary Recovery To Exist. Oven & Incin.	99,500	2,300	49,700	29,000	139	1.0
(To Controlled Oven)	(58,500)		(16,300)			
(or)						
Add Oven Air Preheat To Exist. Oven, Incin. & Primary; 2.1 MM Btu/Hr.	65,800	2,300	33,700	29,000	91	1.4
(To Controlled oven: 2.2 MM Btu/Hr.)	(23,100)	(1,800)	(35,400)	(23,000)	(124)	1.1

the incinerator was $126,500 with an incremental annual operating cost of $18,800. The total annual fuel cost for the controlled oven and incinerator was determined to be $100,000. The plant is allowed to maintain production by meeting VOC emission control requirements, but no return on investment or payback is realized. To offset the increase in fuel cost for VOC emission control, secondary heat recovery can be included in the system. If direct recirculation of 60 percent of the incinerator exhaust volume is returned to the controlled oven, the system annual fuel cost will be reduced to $45,000; a savings of $55,000 annually or 4.1 MM Btu's per hour. The investment cost for this direct recirculation system would be $50,000 which results in a return on investment of 86 percent and a 1.4 year payback assuming an annual operating cost of $4,000. If direct recirculation is not viable, because of product quality liability or if the plant requires process steam, a waste heat boiler can be installed to recover the sensible heat in the incinerator exhaust. A waste heat boiler would not reduce the fuel cost for the curing operation, but would save $72,400 annually in the steam plant. The return on investment is 115 percent with a 1.1 year payback assuming an investment cost of $40,300 and an annual operating cost of $17,700. This boiler will generate 5,300 pounds per hour of 40 psig steam.

Case II—Actual Coating Line

This example case is an actual coating line consisting of a curing oven and catalytic incinerator with primary heat recovery. The existing oven is operating at 2 percent of the LEL, 5000 scfm of dilution air flow, 340° F operating temperature, with a product/conveyor work load of 30,500 pounds per hour. The annual fuel costs for the oven alone is $71,100, assuming a fuel cost of $2.70 per million Btu's. The combined annual fuel cost for the oven and catalytic incinerator* is $149,200. If LEL microcomputer control was added to the oven, the oven annual fuel cost would be $48,300; a savings of $22,800. The resulting return on investment and payback is 2 percent and 8.7 years, respectively, assuming an investment cost of $120,000 and operating cost of $15,100. For the oven alone this would not be a wise investment, but including the incinerator in the analysis makes the economics become more favorable. The annual fuel costs for the controlled oven and catalytic incinerator would be $74,800; a savings of $74,400 annually. Also the investment cost for this incinerator would have been lower than the actual $172,500, since the air load would be greatly reduced at 35 percent of the LEL. It should be noted that the 35 percent of the LEL is the maximum solvent concentration in this case, since levels greater than 35 percent would result in an incinerator exhaust temperature greater than the maximum allowed for this equipment.

The addition of primary heat recovery to the incinerator reduced the fuel costs to $99,500 for a savings of $49,700 annually. This required a $29,000 investment for a 139 percent return on investment and a payback of 1.0 year assuming an operating cost of $2,300. Adding primary heat recovery to the controlled system, the annual fuel cost would be $58,500 for a $16,300 savings. To further reduce fuel costs, secondary heat recovery, oven air preheating for example, could be included in this existing installation. The existing system annual fuel cost would be $65,800 for a $33,700 savings. A 91 percent return on this $29,000 investment and a 1.4 year payback would result assuming an annual operating cost of $2,300. For the controlled system, the annual fuel costs would be $23,100 for a $35,400 savings. This investment of $23,000, assuming an annual operating cost of $1,800, would result in a 124 percent return on investment and a 1.1 year payback.

SUMMARY

The benefits of the CCA Project to evaluate and demonstrate computer control of the dilution air flow in curing ovens are numerous and include environmental, energy, safety, and investment cost factors. Improved control of oven air flows will permit many plants to operate the curing ovens close to the maximum allowable solvent concentration. Since the control systems are installed at the source of the VOC emissions, the industry would achieve the following major benefits:

1. Reduced fuel usage in curing ovens.
2. Reduced fuel usage and investment costs for VOC emission control add-on devices.
3 Improved VOC destruction efficiency
4. Improved operational safety by computer control.

Emissions From Open Top Vapor Degreasing Systems

Charles H. Darvin*

INTRODUCTION

Vapor degreasers are used in most metal finishing plants to remove dirt and grease from various metal parts with nonaqueous organic solvents. Major users include automotive parts manufacturers, metal fabricators, machinery manufacturers, and some electroplaters. In these units, the part to be cleaned is dipped in an organic solvent vapor. Vapor condenses on the part, rinsing off dirt, oil, and grease. The vapor is not contaminated from previous cleaning cycles, as would be the case in a liquid dip tank, so excellent cleaning results. The solvent vapors, which are heavier than air, form a stable vapor layer at the top of the degreaser. Emissions occur when this vapor layer is disturbed.

Emissions from degreasers contribute a significant amount of volatile organic compounds (VOC) to the atmosphere each year. Solvent degreasers alone emit approximately one million metric tons of solvent annually, about 4 percent of total national VOC emissions from stationary sources. Most of these emissions are in and around urban areas where there is the highest concentration of metal working industries. The U.S. Environmental Protection Agency (EPA) thus considers it important that methods of reducing these emissions be developed. Reduction of these emissions would also serve to conserve valuable petroleum products. This paper summarizes a comprehensive testing program which examined the operating conditions that cause VOC emissions from open top vapor degreasers.

THE PROJECT

In late 1977, EPA's Industrial Environmental Research Laboratory in Cincinnati (IERL-Ci) initiated an extensive research program to investigate the characteristics of VOC emissions from open top vapor degreasing systems. The initial requirements of the program required the identification of knowledgeable people and organizations in the field of degreaser technology and the construction and instrumentation of a suitable laboratory facility. PEDCo Environmental, Inc., of Cincinnati conducted the program at its research facility outside Morrow, Ohio, a location which provided a remote area for the testing, free of any urban industrial interferences that could have created false data. In formulating the experimental scenarios and designing the laboratory facility, PEDCo and IERL-Ci relied extensively upon the expertise of the ASTM D-26 Committee on Degreasing, NIOSH, OSHA, and various industrial companies which make or utilize degreasers.

The test program was initially scheduled to run for 12 months, but experimental results indicated the need to expand the number of operating scenarios that should be investigated. The program was therefore divided into two phases. During Phase I, the laboratory was set up, experimental variables were identified, and calm air experiments were conducted. During Phase II, the effects of higher air velocities across the open top of the degreaser were investigated.

EXPERIMENTS AND RESULTS

The following operational procedures and modifications were determined to have the greatest influence on emissions:

- use of covers
- ratio of cross-section of load to that of degreaser
- hoist speed
- freeboard ratio (the ratio of the freeboard height to the smaller interior dimension [length, width, or diameter])
- use of refrigerated freeboard chillers (RFC)
- physical properties of the solvent (e.g., vapor pressure differences)

The experiments were conducted at a relatively constant temperature of 70° F (±10°) and constant humidity. During Phase I of the program, the draft across each system was maintained at calm conditions (0.2 m/sec [40 ft/min]). Phase II experiments were conducted at higher draft velocities (0.67 m/sec [132 ft/min] and 1.2 m/sec [240 ft/min]) across the degreaser. Over one hundred experiments were conducted during Phase I of the program, and another fifty during Phase II. Each experiment was run for roughly 24 hours.

Operational Procedures

Cover - The use of a machine cover was shown to produce significant reductions in solvent emission rates when operating in relatively calm air conditions. Machines containing 1,1,1-trichloroethane (TE) and methylene chloride (MC) were monitored in an idle state over a 24-hour period. These experiments were conducted with and without covers at 0.50 freeboard ratio; results are shown in Table 1.

Although the absolute results of each experiment differ, the general trend was a reduction in emissions up

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Table 1
Effect of Lid Position in Reducing Solvent Loss From Idle Degreaser (50 percent freeboard ratio, RFC off)

Solvent	*Nonboiling*		*Boiling*	
	Run 1	*Run 2*	*Run 1*	*Run 2*
	Solvent loss reduction, %			
TE	0	40	5	60
MC	23	60	33	35

to a maximum of 60 percent. This confirms the capability of a simple work practice procedure to reduce emissions from an idle degreaser.

Load cross-sectional area - A second work practice variable that was determined to affect the rate of emissions from a degreaser was the ratio of the cross-sectional area of the load to that of the open top of the degreaser. Special loads were fabricated to correspond to loads of 50 percent of the system top area (the manufacturer's recommended load) and 70 percent. It was found that in every operating scenario the rate of emissions increased with this increase in load cross-sectional area. As can be seen in Figure 1, increases of emissions from 10 to 50 percent were experienced in systems operated at a 70 percent load cross-sectional area compared to those operating with a load area of 50 percent. This demonstrated that operation of a degreaser within operating specifications significantly holds down emissions.

Machine Modifications

Hoist speed - Increased hoist speed was found to influence emission rates from an operating degreaser. Experiments were conducted using two hoist speeds, 0.04 m/sec (8 ft/min) and 0.08 m/sec (16 ft/min). The results shown in Figure 2 demonstrate typically greater emissions (i.e., lower solvent loss reduction) when operating at the higher speed. It can also be seen that at 100 percent freeboard ratio, emissions are significantly greater at the higher hoist speed. This indicates that hoist speed may significantly influence the capability of an increase in freeboard height to reduce emissions.

Crosscurrent air velocity - The degreasing machines were operated at draft velocities ranging from calm air of approximately 0.1 m/sec (20 ft/min) to greater than 1.0 m/sec (200 ft/min) to evaluate the effects of crosscurrent air velocities across the open degreaser top. The results are shown in Figure 3. In all operating scenarios, increased draft velocities resulted in increased emissions from the machines. At a crosscurrent velocity of 0.67 m/sec (132 ft/min), as much as a 100 percent increase in emissions was observed.

Freeboard ratio - Experiments into the capability of increased freeboard ratio to reduce emissions were conducted over the total range of operational conditions, including calm and high draft conditions, use of covers and refrigerated chillers, and varying load cross-sectional areas. Table 2 presents results with and without a refrigerated chiller and shows that increasing freeboard ratio can significantly reduce emission rates. When freeboard ratio was increased from 0.5 to 0.75 for TE, there was a 20 percent reduction in emissions for TE and a 15 percent reduction for MC.

Table 2
Effect of Freeboard Ratio in Reducing Solvent Loss From Operating Degreaser at 50 Percent Load Area, 0.04 m/s Hoist Speed, and Calm Air

Solvent	*Freeboard ratio, %*		
	50	*75*	*100*
	Solvent loss reduction, %		
Without RFC:			
TE	2	17	50
MC	2	22	22
With RFC (-29°C to -40°C)			
TE	8	44	44
MC	22	44	55

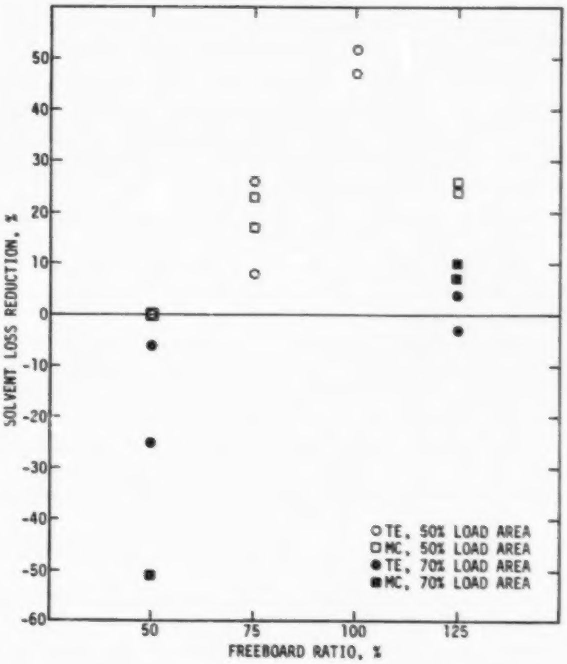

Fig. 1—Effect of load area in reducing solvent loss from operating degreaser at hoist speed of 0.04 m/s (RFC off).

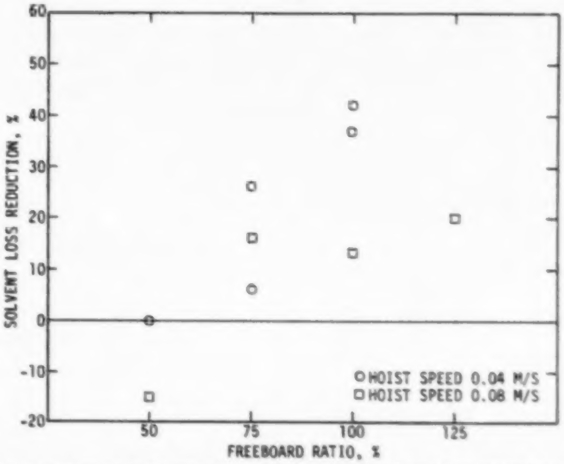

Fig. 2—Effect of hoist speed in reducing solvent loss from operating degreaser using TE and 50% load area (RFC off).

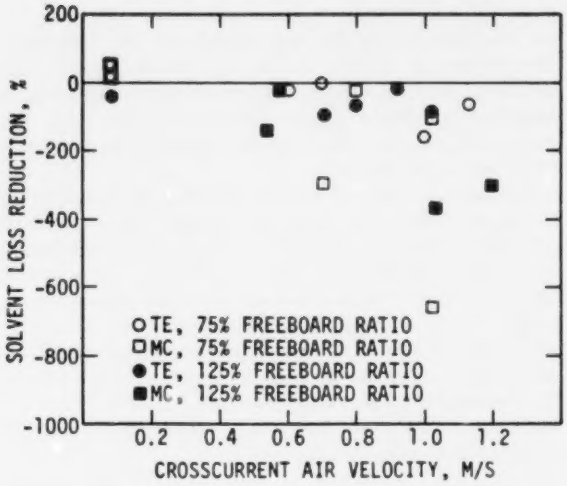

Fig. 3—Effect of crosscurrent air velocity on solvent loss from operating degreaser at 0.04 m/s hoist speed and 50% load area (RFC off).

Machines built to use MC typically employ a 0.75 freeboard ratio. When increasing the freeboard ratio from 0.75 to 1.00 for MC, there was a further 30 percent reduction in solvent loss. Figure 1 also illustrates the benefits of increased freeboard ratio.

Table 3 illustrates the effects of increased freeboard ratio at various crosscurrent air velocities.

The table also contains one case which reverses the general trend of a decrease in emissions with higher freeboard ratio.

An increase in emissions was observed when operating at 0.67 m/s with TE. This could not be explained by the chemical or physical properties of the solvent, and will be the subject of additional testing.

Refrigerated freeboard chiller - A refrigerated freeboard chiller (RFC) can be mounted above a degreaser to reduce emissions from the bath. Experiments with an RFC demonstrated a general reduction in emissions from the degreasers when using MC, as shown in Table 4.

Table 5 shows the effects of operating at higher draft velocities with RFC. It also shows for TE a reversal of the trend toward reduced emissions with an RFC that was observed with MC.

Table 3
Effect of Freeboard Ratio in Reducing Solvent Loss From Operating Degreaser at Various Air Velocities and 50 Percent Load Area and 0.04 m/s Hoist Speed (RFC Off)

Solvent	*Air velocity, m/s*	*Freeboard ratio, %* 50	75	125
		Solvent loss reduction, %		
TE	0.1	0	20	50
	0.67		-10	-50
	1.12		-120	-50
MC	0.1	0	10	15
	0.67		-160	-100
	1.12		-380	-350

Table 4
Effect of Refrigerated Freeboard Chiller (RFC) in Reducing Solvent Loss From Operating Degreaser Using MC at Greater than/Equal to 0.67 m/s Air Velocity

Refrigerant temperature, ° C	*Freeboard ratio, %*	*Solvent loss reduction, %* RFC off	RFC on
0	75	-450	-220
	125	-250	-220
-29 to -40	75	-75	-75
	125	-120	-20

Table 5
Effect of Higher Crosscurrent Air Velocities in Reducing Solvent Loss From Operating Degreaser At 0.04 m/s Hoist Speed

Solvent	*Air velocity, m/s*	*Freeboard ratio, %*	*Solvent loss reduction, %* RFC off	RFC on
TE	0.67	75	-100	-200
		125	-150	-200
	1.2	75	-110	-180
		125	-50	-180
MC	0.67	75	-250	-150
		125	-175	-150
	1.2	75	-360	-260
		125	-320	-230

DISCUSSION OF RESULTS

A number of significant conclusions can be developed about the nature and control of emissions from degreasers as a result of this evaluation program. Use of simple operating procedures such as low hoist speeds, closing of the system lid when in idle condition, and shielding the system from high draft velocities can significantly reduce emissions. These changes, however, require a conscious and continuous effort on the part of the operator. Passive control options such as increased freeboard and refrigerated chillers were shown to be just as effective and require only installation and maintenance for continuous control.

The data also show the capability of each control option when used separately or in tandem. It was shown that secondary chillers achieve greatest control benefit at lower freeboard ratio levels, 0.5 for MC and 0.75 for TE. As freeboard ratio increases, its capability approaches that of the secondary chiller. This was found to be true at both lower and higher crosscurrent air velocities for MC. However, this trend was found to be reversed with TE, and no viable explanation based on chemical or physical properties of the solvent has been found. An extension of the program to include approximately 30 or more experiments has therefore been scheduled. During those experiments, a more detailed evaluation will be made of secondary operating variables such as ambient conditions and aerodynamic effects.

The conclusions that have been and will continue to be developed after completion of the testing can have a major impact upon future degreaser design and operating practice. Both plant layout and production line scheduling can be impacted. To reduce emissions, a degreaser should be placed in a location shielded from high drafts, either by installation of baffles or by proper placement in the plant. Hoist speed should be maintained at relatively low velocities (which could require control of the speed of the production line). The maintenance of loads at low cross-sectional area could also limit production rates. Finally, the use of add-on control options could influence equipment location in the plant. These operating practices and design modifications, however, represent in most cases relatively inexpensive options and would produce only minor changes in normal plant operations.

A summary report of the Phase I efforts is in preparation. This report will include the results of experiments conducted primarily under calm air conditions. It will be available for distribution in July 1980. The Phase II report is awaiting completion of the remaining 30 experiments analyzing the unusual TE results. It will be ready for distribution in September 1980.

V.O.C. Control Efforts By A Heavy Duty Truck Manufacturer

Edward W. Kline*

Can you visualize a 9.9 mile traffic jam? That's the distance the line of tank trucks would stretch if one thousand and forty-three of them were parked bumper to bumper. It would take 1043 tank truck deliveries to supply 7.3 million gallons of #2 fuel oil.

I mention these figures because 7.3 million gallons is the amount of #2 fuel oil it would take if we were to incinerate Volatile Organic Compound emissions from painting operations at Mack Trucks Allentown Assembly Plant.

To get a better feel for the magnitude of these figures, consider the following:

> If you round off the cost of a gallon of #2 heating oil at $1.00 per gallon, you have an annual oil bill of 7.3 million dollars. Average that over the 20,000 trucks we built in Allentown last year and it would cost an additional $365 to paint a truck.
>
> If you use 1500 gallons of #2 oil to heat your home each year, 7.3 million gallons would be enough oil to heat a city of 4866 homes. Now even if this quantity of oil were available, which it is not, one has to ask—Is such conspicuous consumption advisable given our present world situation?

I am sure most of us recognize the importance of V.O.C. control. The EPA has presented convincing facts, figures, and statistics to serve as incentives.

However, it is my firm belief that as Environmentalists, Scientists, Engineers, Enforcement Agencies, and Industrial Managers, it is our responsibility to accomplish this control in an effective and economical manner.

As I see it there is no one universal solution to the problem of V.O.C. control. That is of course unless there is a revolutionary breakthrough in coating technology.

Each process should be examined on an individual basis if you want to determine the most favorable control technology. Let's review the circumstances affecting our decisions at Mack Allentown.

PRODUCT REQUIREMENTS

Mack Trucks are separately engineered to meet customer specifications and individual needs. We are custom truck builders.

The trucks we build cost in the neighborhood of $50,000. Unlike most automobiles, our entire truck is painted—chassis and all. The projected life expectancy is 5 - 10 years. However, some are in use more than 20 years and still going strong. It is not uncommon to hear customers talk about breaking the million mile mark with their Mack.

Mack Trucks are in use around the world and are exposed to weather conditions which range from desert heat to arctic cold. Naturally, our customers also expect the finish to meet certain requirements such as: Long Term Weather Durability; Color Choice and Appearance Hi-Luster; Color and Gloss Retention; Ability to Withstand Extreme Environmental Conditions such as Heat, Cold, Abrasion, Corrosion, and contact with Chemicals & Oxidation; Chip Resistance.

As you can see, living up to these tough expectations requires a paint finish highly durable in nature. We use Thermo-set acrylic enamels to meet these requirements.

TYPES OF ENGINEERING CONTROLS

A. Improved surface coating transfer efficiency. Looking at both ends of the spectrum, we find conventional air atomization spray painting has a transfer efficiency of 30 - 60%.

Airless electrostatic spray painting has a transfer efficiency of 80 - 90%.

B. Materials Substitution—By weight an average gallon of solvent base paint contains between 4.5 - 6 lbs. of V.O.C. An average gallon of water borne coating contains between 2 - 3.5 lbs. of V.O.C.

C. Physical Controls—Carbon Absorption systems are being utilized. This type of V.O.C. control ranges in efficiency from 40 - 90%. Generally carbon absorption is being used when quantities of air are reasonable.

Catalytic and direct incineration systems have been rated at 90 - 100% V.O.C. control efficiency.

Refrigeration systems used for low volumes of air range from 40 - 80% V.O.C. control efficiency.

SUCCESSFUL APPLICATIONS AT MACK TRUCKS ALLENTOWN ASSEMBLY PLANT

Chassis Spray Painting

Conventional spray painting has been the industry standard for years. We replaced conventional chassis air atomization spray painting with airless electrostatic techniques. This reduced V.O.C. emissions by 21 tons per year.

Small Parts Painting

Our small parts painting operations includes a wide variety of parts that range in size from doors to brackets. A total of 72,000 square feet of surface coating is completed in an 8 hour shift.

In this operation a combination of materials substitution, improved transfer efficiency, and catalytic

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Environmental Control
Mack Trucks, Inc., Allentown, PA

incineration are used to eliminate 40 tons of V.O.C. emissions annually.

Substitution of Materials and Improved Transfer Efficiencies

Many parts which had been painted by conventional air spray methods now receive electrophoretic paint coatings.

The electrophoretic coating takes place in a 13,000 gallon dip tank. It is a water borne coating which contains 1.9 lbs. of V.O.C. per gallon of coating. Plating voltage of the system ranges from 250 - 350 volts D.C. The current density is 5 amps/sq. ft.

Air and airless electrostatic painting techniques are being evaluated and perfected for color spraying operations.

Emission Control Technology

Exhaust air from 3 paint drying ovens is funneled through a catalytic incinerator. In an 8 hour shift 4.8 million cubic ft of air passes through the incinerator. Oven temperatures are maintained at 250° F (121° C) for paint drying. The incinerator is a Schweitzer Sicor unit. It contains 9 cubic feet of DuPont Torvex Platinum Catalyst. The Catalyst allows incineration to take place at temperatures between 700 & 900° F. Fifty gallons of #2 heating oil are consumed each hour to operate the incinerator.

John Kroehling of DuPont worked closely with us on this project. John expects the Catalyst to last 3 - 5 years.

The 9 cubic feet of Platinum Catalyst is designed in a honeycomb fashion. The honeycomb effect produces 300,000 square feet of catalytic contact surface area.

Heat Recovery

Indirect heat recovery is used to reclaim 4 million BTU's of incinerator heat each hour. The recovered energy is used to heat the Electropheretic dip oven to a temperature of 350° F.

The recovered heat and lower temperature requirements of the catalytic incinerator produce an annual savings of 53,000 gallons of #2 home heating oil. That's enough oil to heat 35 - 40 homes in the Lehigh Valley each year.

CONCLUSION

As I see it, there is no universal solution to the control of V.O.C. emissions unless a breakthrough in coating technology occurs. A combination of improved transfer efficiency of coatings and materials substitution, when practical, appears to be the most favorable approach to V.O.C. control.

Incineration with heat recovery has application when an energy balance can be obtained. The use of carbon absorption or refrigeration principles have application when air volumes are low enough, or when there is a desire to recover lost product.

The most effective results will be obtained by carefully examining the merits of each process in conjunction with the control applications which are available.

Centralized Treatment and Disposal of Special Wastes in the Federal Republic of Germany

N. Roesler*

INTRODUCTION

In "Environmental Protection" and, generally, in the "Improvement of Quality of Life", special wastes in the form of gases, liquids, and solids, and even noise are becoming more and more important in comparison with normal municipal sewage and garbage. Although the legal task of the public Wastewater Treatment plants is the acceptance and treatment of normal municipal wastewater, we found that we were struggling to treat unusual waste components, which, despite federal laws and municipal regulations, entered into the sewers and complicated the treatment of wastewater. Different Institutions, therefore, have become concerned with various branches of industry and their liquid wastes. Since about 1960, in the Federal Republic of Germany, intensive efforts have been made which have resulted in various more or less, centralized treatment plants with facilities for treating the wastes coming from different industries

ORGANIZATION

An example of facilities based on more private and voluntary activities is represented by the Ruhrverband which comprises a part of the land of Northrhine-Westfalia.

The central Decontaminating Plant, Iserlohn (ZEA-Iserlohn), the first plant in West Germany, was completed in 1964. This plant treats metal finishing wastes from an area of 380 km^2, comprised of the town of Iserlohn and eight municipalities, forming the district of Iserlohn. In this area, there are about 200 installations, in most cases medium-sized industrial enterprises which are running approximately 1000 baths for galvanizing, anodizing and non-ferrous metal pickling, with a total volume of roughly 1000 m^3. (See Figure 1)

After obtaining the agreement of all the associates concerned, the Corporation for the Advancement of Industry Ltd., Iserlohn, took over the responsibility for metal finishing waste treatment in this area, and charged the Ruhrverband for planning, constructing and operating the plant, in accordance with section 3 of the Ruhr Pollution Act (law of the regional government of Northrhine-Westfalia).

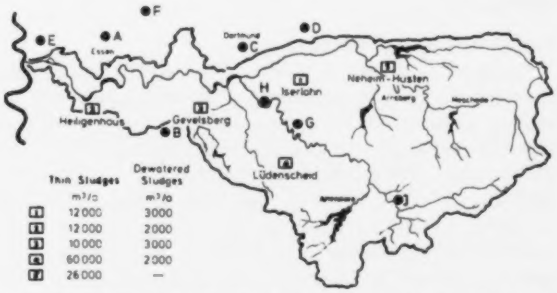
F
E
A
Essen
Dortmund
C
D
Neheim-Husten
Arnsberg
Meschede
H
Iserlohn
Heiligenhaus
Gevelsberg
B
G
Lüdenscheid
J
Thin Sludges m³/a
Dewatered Sludges m³/a
12 000
3000
12 000
2000
10 000
3000
60 000
2000
26 000
—

Fig. 1—Central Plants for the Treatment of Hydroxide Sludges in the Catchment of the River Ruhr.

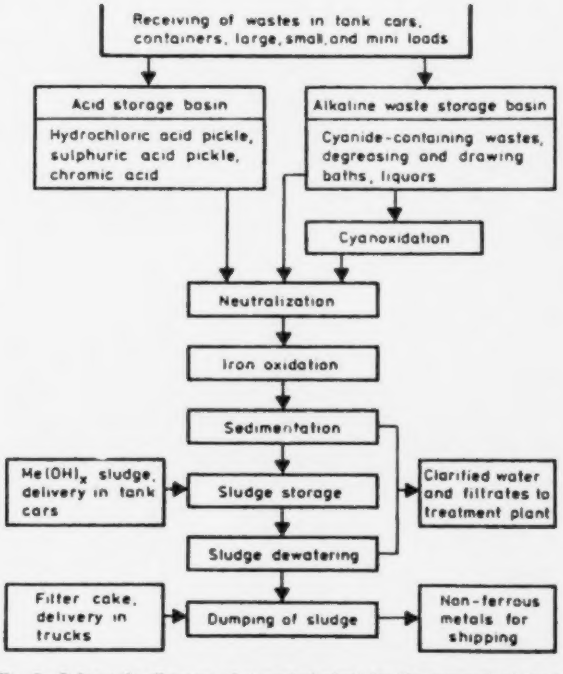
Receiving of wastes in tank cars, containers, large, small, and mini loads
Acid storage basin
Hydrochloric acid pickle, sulphuric acid pickle, chromic acid
Alkaline waste storage basin
Cyanide-containing wastes, degreasing and drawing baths, liquors
Cyanoxidation
Neutralization
Iron oxidation
Sedimentation
Me(OH)x sludge, delivery in tank cars
Sludge storage
Clarified water and filtrates to treatment plant
Sludge dewatering
Filter cake, delivery in trucks
Dumping of sludge
Non-ferrous metals for shipping

Fig. 2—Schematic diagram of a central plant for the removal of toxic substances from electroplating plants and pickling plants.

The ZEA-Iserlohn plant is divided into three sections (Figure 2). The first section comprises the collection tanks, and the cyanide oxidation and chromate reduction facilities. Section two is the neutralization and desludging facility for wastes coming from section one, as well as for acid and alkaline solutions from aluminum-anodizing plants, and iron and non-iron pickling plants. The third section comprises the following steps: thickening, dewatering and disposal of hydroxide sludges coming from section two. It also handles sludges

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Department of Sewage Treatment
Ruhrverband D-43, Essen, Germany

delivered from companies which have pretreated their wastes to the extent they have found economical to do in-house. The ZEA-Iserlohn can, therefore, handle toxic concentrations, thin and thickened sludges, and dewatered sludges requiring disposal. This allows each associate to choose the grade of pretreatment which is most economical for him, and consequently, the cheapest way to dispose of his wastes.

In the case of the second plant, the ZSEA-Heiligenhaus, the responsible authority is the Dusseldorf-Mettmann (Figure 3). The various installations in this area preferred to handle the first and second sections (as described above) of wastewater treatment within their own plants. Hence the Ruhverband planned and constructed a storage, dewatering and dumping facility for sludges from Heiligenhaus and has been operating since 1968. Unlike the ZEA-Iserlohn, membership is compulsory for all the installations unless one can prove that wastewater discharges from his own plant comply with the law.

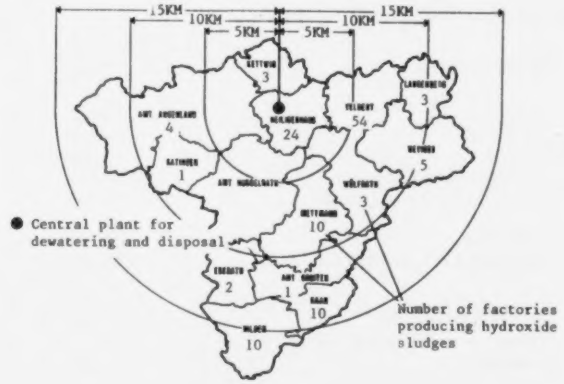
15KM
10KM
5KM
5KM
10KM
15KM
3
4
24
54
3
1
5
3
10
2
1
10
10
● Central plant for dewatering and disposal
Number of factories producing hydroxide sludges

Fig. 3—District Dusseldorf-Mettmann concentrations of factories in the district.

A third plant has been constructed by the town of Ludenscheid and a private garbage collector is running it for another 100 installations.

Two further plants run by private contractors are handling emulsions from rolling mills and another one is collecting and recovering spent hydrochloric acid.

These plants have become the central collection and treatment facilities for all special wastes coming from the metal finishing industry in this area.

Managing

The technical supervision of the two plants operated by the Ruhrverband is handled by two engineers in cooperation with two nearby wastewater treatment plants. The engineer involved in each case is able to add or withdraw workers according to need. Normally, two workers are required to operate the plant in Iserlohn and one in Heiligenhaus.

The financial management is done by a group of elected men who represent the industry (associates), the responsible corporation, the local authorities, the Ruhrverband, and the Chamber of Commerce. Each year, the financial statements and plans for the following year are presented by the managing engineer to the representatives for approval.

Financial Aspects

For financial purposes, the metal finishing industry (galvanizing, anodizing and pickling factories) in Iserlohn has been separated into three groups according to the volume of their baths, the amount of chemicals bought, the quantity of process water needed, the quantity of sludge produced, and so on. Also taken into account is the degree of participation or the amount of pretreatment carried out by the companies themselves. A small plant wanting to participate in all steps of central treatment may pay, for instance, 5000-DM, while a large company which sends only dewatered sludge for dumping may pay 20,000-DM for the disposal.

In addition, the Ruhrverband has granted a loan of 150,000-DM, the town of Iserlohn a lost subsidy of 50,000-DM and the regional government another lost subsidy of about 200,000-DM, towards the costs of the Central Plant. The construction costs for the Central Treatment Plant for Iserlohn, including a second filter

TABLE 1
CHARGES FOR THE USE OF TWO CENTRALIZED PLANTS FOR REMOVAL OF INDUSTRIAL TOXICANTS, IN DM PER CUBIC METER

	*Central detoxification plant Iserlohn**			*ZSEA*** *Heiligenhous*
	1. Construction phase		*2. Construction phase*	
Members participating, non-members = not participating in the construction of the installation	*Non-members*	*members*	*Non-members*	*members*
Acid and Cr acid semi-concentrate	150. - DM			
Acid and Cr acid concentrate	200 - DM			
Semi-concentrate containing CN	170 - DM			
Concentrate containing CN	247 - DM			
Eluate from ion exchangers	90 - DM			
Acid pickling waste waters		74.50 DM	87.60 DM	
Spend pickling fluid containing sulphuric acid		—	113.80 DM	
Pickling fluid containing = 5 g Cu/l		29.50 DM	52.60 DM	
Pickling fluid containing = 15g Cu/l		20. DM	20. DM	
Dilute sludge ~ 3% DS		6.55 DM	9. DM	17.40 DM
Dewatered sludge ~ 30% DS		12.50 DM	19.50 DM	16. DM

* excluding shipping costs and value added tax
**including shipping costs and value added tax

TABLE 2
RUNNING COSTS FOR CENTRAL NEUTRALIZATION, 1974

Receipts	DM	Expenditures	DM
Neutralization of liquids from		Wages	23,500
		Chemicals	32,100
11 members	28,900	Energy	1,600
		Costs for sludge handling	80,800
about 50 non-members	300,500	Maintenance	66,600
		Reserves for maintenance	40,000
		Insurance for risks	20,000
Receipts from liquids sold	600	Technical and administrative supervision	47,400
		Reserves for unforeseen	32,200
Interest for reserves	15,800	Transport costs for concentrates sold	1,600
	345,800		345,800

TABLE 3
RUNNING COSTS FOR SLUDGE HANDLING AND DISPOSAL

Receipts	DM	Expenditures	DM
19 members		Wages	28,800
dewatered sludge	26,600	Chemicals	3,600
thin sludge	11,200	Energy	2,000
		Transport and Disposal	18,000
non-members		Reserves for recultivation	15,700
dewatered sludge	7,800		
thin sludge	50,300	Maintenance	69,600
costs for special treatment	6,500	Reserves for maintenance	30,000
Hydroxide sludges from central plant (galvanizing industry)	31,200	Insurance for risks	3,200
Hydroxide sludges from central plant (pickling industry)	80,800	Technical and administrative supervision	21,400
Interest for reserves	21,500	Interest for loan	5,200
		Reserves and unforeseen	28,400
	235,900		235,900

TABLE 4
SUMMARY ON STATUS AND DEVELOPMENT OF SPECIAL RESERVES

Central Neutralization	Status 31/12/73 1967-1973 DM	Withdrawal 1974	Increase 1974	1967-1974
Reserves for maintenance	85,000	− 10,000	+ 40,000	115,000
Reserves for unforeseen	95,900	− 15,000	+ 32,000	112,900
Central Sludge Handling				
Reserves for recultivation	40,700	− 6,700	+ 15,700	49,700
Reserves for maintenance	45,000	− 10,000	+ 30,000	65,000
Reserves for repayment of loan	105.000	—	—	105,000
Reserves for unforeseen	47,700	− 11,200	+ 28,400	64,900
				512,500

press and a second dump for about 50,000 m,[3] totaled 2 million DM. The second filter press and the second sludge depository were paid for from savings on the operating costs.

Similar financing has been arranged for the ZSEA-Heiligenhaus. In a third case, construction costs were paid for through a loan, so that the capital cost, (interest and repayment) must be calculated as part of the operating costs.

The operating costs for the ZEA-Iserlohn are shown in Tables 1, 2, 3 and 4. They are lower than for any other central treatment plant in Western Germany; most costs have not risen for 16 years. An example of the annual calculation of profit and loss can be seen in Table 2, for neutralization, and in Table 3, for sludge handling. The status of special reserves is shown in Table 4. In the past, all necessary expansion programs have been paid for out of the special reserves.

If the capacity allows, waste is also accepted from the so-called non-members. They must, however, pay a higher price than members for the service.

Preparation, Collection and Transportation Of the Wastes

A minimal pretreatment must be carried out by the companies themselves. First, the quantity of rinsewater must be reduced through improved rinsing techniques. This can be achieved either by using a still-rinse after the bath and two or three counter current rinses, or by using a more technically advanced method: one still-rinse and one flow-rinse in combination with ion-exchangers (Figures 4 and 5). The first method results in so-called semi-concentrates and a lesser quantity of rinsewater. These must either be treated in the plant, or stored in a tank until a quantity has been collected which can be economically transported to the central treatment plant.

In the second method of still-rinse, flow-rinse and ion-exchangers, a very low quantity of freshwater is needed to make up the losses in the rinsing cycle, but different storage tanks must be provided for the acid and alkaline solutions.

For collecting, storing and transporting the liquors, we offer containers of different size (60; 200; 800 liters) without any additional payment. If the quantities are greater, it may be more economical to build some storage tanks in the plant itself and transport by 5-, 10-, or 20-m^3 trucks. This is being done, for instance, when thin sludges from in-plant treatment facilities have to be transported once or twice a month to the central treatment plant.

In the case of the central dewatering facility in Heiligenhaus, transport of the wastes from the industrial plants to the facility is handled by one transport company which charges the same price, regardless of the distance involved. This cooperative principle eliminated disagreement about the location of the facility and possible economic disadvantages which may have occurred in transporting the wastes.

Operation and Maintenance - Recovery of Liquids

This paper is not intended to give the chemistry of the oxidation of cyanides, or of the reduction of chromates, or of neutralization. The following section details some of the experiences we have had with out central plants and the solutions we found to some problems.

We found that one of the most important items was storage capacity. Adequate storage capacity saves on time and expenses for chemicals and, therefore, on operating costs. For instance, when the central plant for Iserlohn was started, we found that a large quantity of $NaHSO_4$ was required for the reduction of chromates. We began to collect and store iron-chloride and iron-sulphate solutions for use instead of $NaHSO_4$. This eliminated the need to buy expensive chemicals which, in any case, increased the salt concentration in the effluent. We also store the alkaline solutions we collect, for use in neutralization, as well as in the oxidation of cyanides, as a substitute for sodium hydroxide. Alkaline solutions are also used to dilute concentrates to 1 g CN/l. Certain concentrates, in most cases small quantities, can also be collected, equalized in quality and be prepared for recycling if storage space is available. We are collecting some hundred m^3/year of copper and nickel containing solutions, which are transported in 20 m^3 containers to a central non-ferrous-metal recovery plant operating on a private basis. Some of the industrial installations are now collecting these solutions themselves, rather than having the central treatment plant do so.

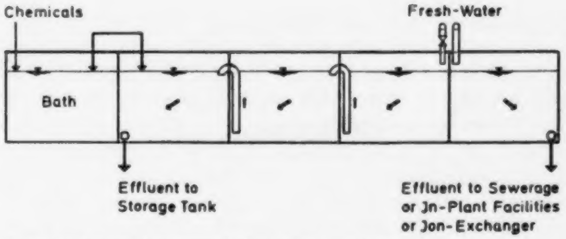
Chemicals
Fresh-Water
Bath
Effluent to Storage Tank
Effluent to Sewerage or Jn-Plant Facilities or Jon-Exchanger

Fig. 4—3-step-counter-current rinse with flow-rinse.

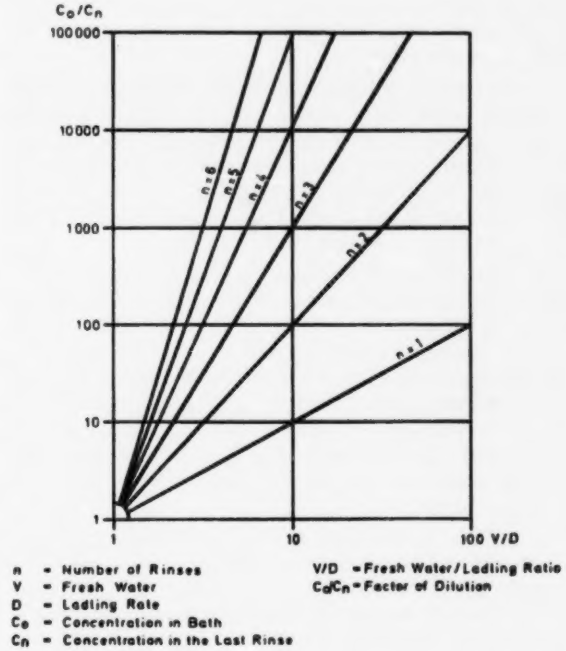

Fig. 5—Water consumption of counter-current rinse.

		Standards when discharged to a river	Standard A115	Berlin	Frankfurt	Köln	Zürich
Sediment	[ml/l]	0,3	*)	0,5	1	—	—
pH - value		6,5 - 9,0	6,5 - 9,5	6,5 - 8,0	6,0 - 9,0	6,0 - 9,0	6,5 - 9,0
Chromium	[mg/l]	2,0	4,0	1,0	2,0	2,0	2,0
Copper	[mg/l]	1,0	3,0	0,1	2,0	2,0	1,0
Nickel	[mg/l]	3,0	5,0	1,0	2,0	3,0	2,0
Zinc	[mg/l]	3,0	5,0	3,0	2,0	2,0	2,0
Cadmium	[mg/l]	3,0	—	1,0	2,0	2,5	1,0
Iron	[mg/l]	2,0	*)	—	20,0	5,0	—
Tin	[mg/l]	—	—	5,0	—	2,0	2,0
CN decomposable by chlorine	[mg/l]	0,1	1	0,1	frei 0,3 komplex 1,0	0,5	0,5
Free chlorine	[mg/l]	—	—	—	1,0	—	0,5 - 3,0

*) Limits in dependence of the receiving treatment plant

Fig. 6—Standard values for the toxicant content of waste waters when discharged into a sewerage system.

In future, some special solutions will be collected and stored for use in the Ruhrverband's treatment plants. Instead of buying expensive chemicals for phosphate precipitation, we are now using the iron-chloride concentrates from iron pickling plants, after equalizing the concentration and destroying the free hydrochloric acid by adding iron oxide from another central plant which operates on a private basis. This plant is recovering about 2 m^3/h of hydrochloric acid by combusting the spent concentrates. (Figs. 1, 6) This procedure agrees with the "Waste Recovery Program of the Federal Government of West Germany". Adequate storage capacity also makes continuous and stable treatment possible. We are able to accept all quantities of waste (from a beaker to a 20 m^3 container), in all qualities (from concentrates, semi-concentrates, thin and dewatered sludges) at any time.

The pumps are another important consideration in the treatment plant. One should not try to find a pump material which will withstand all challenges. The pumps which can be repaired easily by replacing rotating parts and gaskets after having removed a few screws, and not after dismantling the whole plant, should be used. This also applies to the mixers.

The chemical treatment process must be automated to reduce the number of operators required and to obtain consistent results. A complete central plant which includes chemical treatment and disposal facility really requires only one man to operate it. However, a single man is not permitted to work alone in such a plant, so two men are required for each shift and back-ups are necessary in case of illness, and during vacations. Our back-up operators are supplied from a nearby sewage treatment plant.

Protection from corrosion is another important consideration. Naturally, all storage tanks must be carefully sealed. Even neutralized sludges have a strong corrosive effect, because of their high salt concentrations. Hence the filter press plates should be coated by heating the cast iron plate and dipping it in a fluidized bed of special polymers. Plates manufactured from special plastic could also be used. The effluent from a central plant has salt concentrations of up to 5 g/l SO_4, 1 g/l NO_3^-, and 5 g/l, Cl. NO_2^- and 0.2 g/l NH_4 may also be present. This effluent is, therefore, discharged to the inlet of the wastewater treatment plant, after passing through a final settling tank of long detention time. This treatment is necessary not only to oxidize ammonium and to reduce nitrates, but also to dilute the salts that are toxic to fish.

Disposal, Supervision of the Disposal Site, And Recovery of Special Sludges

The dewatered sludges from the central plant, as well as those from company-owned facilities are dumped at a disposal site. The disposal site usually includes lagoons for anaerobically digested municipal sludges and areas for dewatered hydroxide sludges. The bottom of the site is sealed with clay. Any percolating or surface water is withdrawn and returned to the central treatment plant. There is usually no surface water at all, and the percolating water contains only very small traces of metals, always below the standards required in Germany for waste disposal. (See Figures 6 and 7.)

The disposal sites should be surrounded by trees, or at least by bush, since wind erosion can cause problems.

Special sludges containing copper, nickel and zinc are being stored separate from the iron and chromium containing sludges (Figure 8). If the metal market allows, these sludges are given away for free, in order to save on disposal site space. Liquid and solid material wastes from the electroplating, and brass and copper pickling industries are recycled to save on operating costs, capacity and volume, not to make a profit.

	Dump Iserlohn	Dump Heiligenhaus
Sediment [mg/l]	0,1	0,1
pH - value [mg/l]	7,6	8,0
Copper [mg/l]	0,1	0,2
Zinc [mg/l]	0,1	1,3
Nickel [mg/l]	1,3	0,4
Chromium [mg/l]	0,1	0,1
Iron [mg/l]	0,7	0,9
Cyanide [mg/l]	0,1	0,1

Fig. 7—Contamination of seepage from two centralized industrial sludge dumps.

sludge sample	Cu	Zn	Fe	Cl	S	Ca O	Al_2O_3	H_2O
1	3.35	2.85	0.09	0.17	15.4	29.5	0.15	50
2	11.4	4.7	0.02	0.62	11.9	22.5	0.15	50

Fig. 8—Analysis of Sludges for Recycling

The Ruhrverband collects about 10,000 t/year hydrochloric acid (containing 130 g Fe/l and 5 g free HCl/l), and 20,000 t/year of $FeSO_4 \cdot 7H_2O$ from iron pickling wastes. This represents a real economic factor as a raw material for the chemical industry. However, the sale of these products covers only the transportation costs, although we also save by not having to pay for neutralization, desludging, dewatering and dumping.

Other Wastes that can be Accepted

CN^- and NO_2 salts from hardening furnaces are collected in containers at the industrial plants and sent to a central collection site, (Fig. 1, A) from which they are taken to an old salt-mine and disposed underground. All solid toxic materials are also handled in this way.

Water from cooling baths is occasionally brought to the central treatment plant at Iserlohn. Chemicals from laboratories and from the army (sodium hydroxide, calcium hypochlorite, etc.) are also accepted at the plant. As long as the capacity of our central plant is not exhausted, we accept these materials from all over Northrhine-Westfalia, and even from other parts of Germany.

A bulletin published through the "German Recovery Program" lists various installations which accept special wastes, liquids or solids, toxic or inert, organic or inorganic wastes.

Acceptance of Centralized Treatment Concepts in Other Countries

Several projects for centralized treatment plants are being developed outside of Germany, for example, in Norway, Denmark and Switzerland. However, none of these except Denmark has yet passed the planning stages. Many central facilities for special wastes from various industries are operating successfully in Germany. We have found such facilities to be the best solution to the precipitation, we are now using the iron-chloride concentrates from iron pickling plants, after equalizing the concentration and destroying the free hydrochloric acid by adding iron oxide from another central plant which operates on a private basis. This plant is recovering about 2 m^3/h of hydrochloric acid by combusting the spent concentrates. (Figs. 1, 6) This procedure agrees with the "Waste Recovery Program of the Federal Government of West Germany". Adequate storage capacity also makes continuous and stable treatment possible. We are able to accept all quantities of waste (from a beaker to a 20 m^3 container), in all qualities (from concentrates, semi-concentrates, thin and dewatered sludges) at any time.

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Economics of In-Plant Treatment Versus Shipping to a Central Plant

The decision as to whether it is more economical to treat wastes in an in-house facility or to transport them to a central facility requires careful investigation. The present situation, and possibilities of future development must be examined in each case, and the following items should be taken into account:

1) Cost of in-plant changes.
2) Cost of pretreatment up to desludging (3% solids).
3) Cost of further thickening and dewatering.
4) Cost of transporting and disposing of the filter cake.

If points 1) and 2) are considered in conjunction with the quantity of rinse water required, it is found that, below a certain volume of rinse water, it is more economical to use a central facility. Beyond this volume, it is cheaper to use an in-house facility. Naturally there is also a zone of uncertainty where it is possible to determine which is most economical.

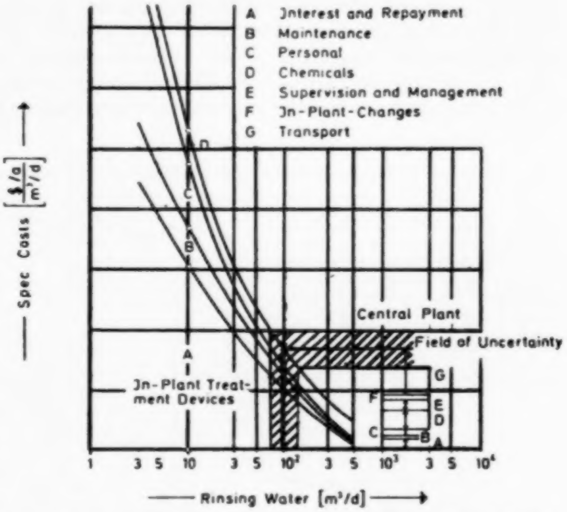

Fig. 9—Specific annual costs of water treatment with in-plant and central stations as a function of rinsing-water quantity (without dewatering and disposal sludges)

Thin sludges and filter cakes must be considered in the same manner, in order to decide whether to handle them directly or ship them to a central treatment plant.

Figures 9, 10, 11 and 12 have been prepared using our data for interest and repayment, operating time, annual depreciation, transportation distances, benefits for government, and savings on the cost of fresh water and sewerage for the municipal treatment plant and associations such as Ruhr River Association and the Ruhr Reservoir Association.

Now let me show you the example. A galvanizing plant, which required 100 m^3 of fresh water per day redesigned its entire processing line and improved the waste treatment sections for each processing unit (Figure 13).

The first step was to improve metal recovery. This means that copper, nickel, zinc and chromium containing liquors must remain either on the surface of the material to be finished or in the bath. How can this be done? If you pull the material out of the bath and take it directly to the

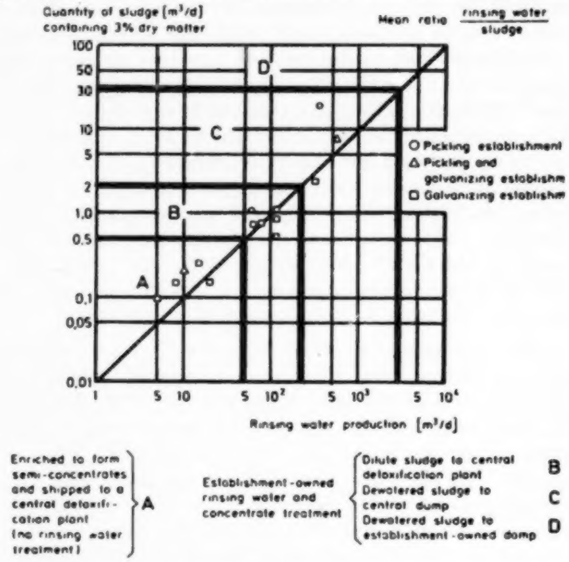

Fig. 10—Organization of toxicant removal subject.

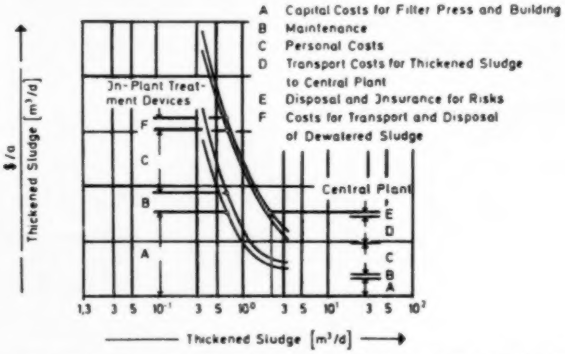

Fig. 11—Specific costs of in-plant and central sludge dewatering devices.

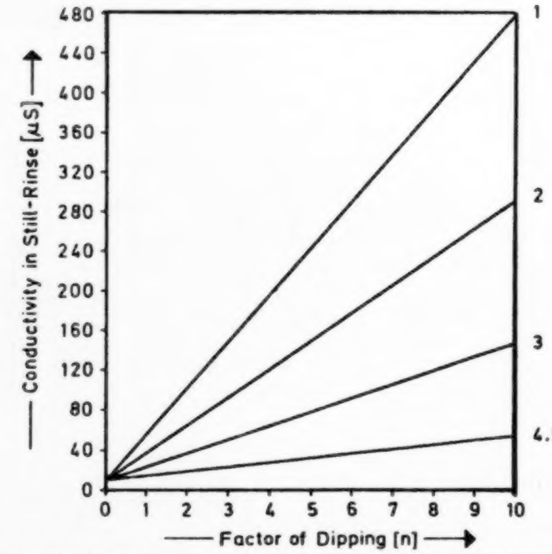

Fig. 12—Bath-losses as a function of the quality of material-removal from the bath.

rinse you remove, let us say, a maximum of 100% of the liquor. If you allow the piece to drip into the bath for 15 seconds, this value drops to about 60% and for 60 seconds, to 30%. By adding an electromagnetic vibrator with variable frequency and amplitude so that the best combination can be determined, you can minimize the bath losses to 10% by vibrating the rack while removing it from the bath. Ladling parts should be suspended so that the concentrates can flow out of the hollows. The rest can be blown out with air. Every percentage you save is your money, represented by the need for less metals or metal salts, less water for rinsing, and less wastewater to be handled. You cannot protect your environment by wasting water and materials and you must concentrate the inevitable losses in as small a quantity of water as possible. Dilution will not keep your water clean.

The next step in good housekeeping is a good rinsing process with counter current water flow and replacement of the losses of the bath from the first still rinse. No matter which rinsing process you use, you will still be getting semi-concentrates, which can be handled as shown. The effluent from the flow rinse goes to the ion-exchanger and is then recirculated to the rinse. With two or three counter current flow rinses, the effluent from the second and third rinses can be sewered since the metal concentration will be under 5 mg/l, while the effluent from the first rinse after the bath represents semi-concentrates containing about 95% of all metal losses. Many other variations of this operation are possible.

Centralized Treatment and Disposal Of Special Wastes in Bavaria*

The following discussion is an example of a more public and compulsory centralized treatment concept.

I. Tasks

The harm caused by the uncontrolled disposal of commercial and industrial wastes has become increasingly evident in recent years, owing to the continuous growth of industrialization. Compared with wastes from households, or domestic refuse, these special wastes occur in relatively small quantities and must receive special treatment in plants designed for the purpose if they are to be disposed of in the proper manner, i.e. with no harmful effects on water, air or the environment and with no adverse effects or pollution caused by dust, odors or corrosive gases.

Such materials, in the broadest sense, also include hospital wastes, scrap vehicles, car tires and the like; the term "special wastes", however, applies only to those materials which, owing to their nature or quantity, cannot be disposed of together with domestic refuse and which none of the existing installations such as those of hospitals, animal carcass processing plants, private shredder installations, centralized graveyards for radioactive materials, etc can take. The decision as to what constitutes special wastes depends both on the individual constituents of the material and on its quantity

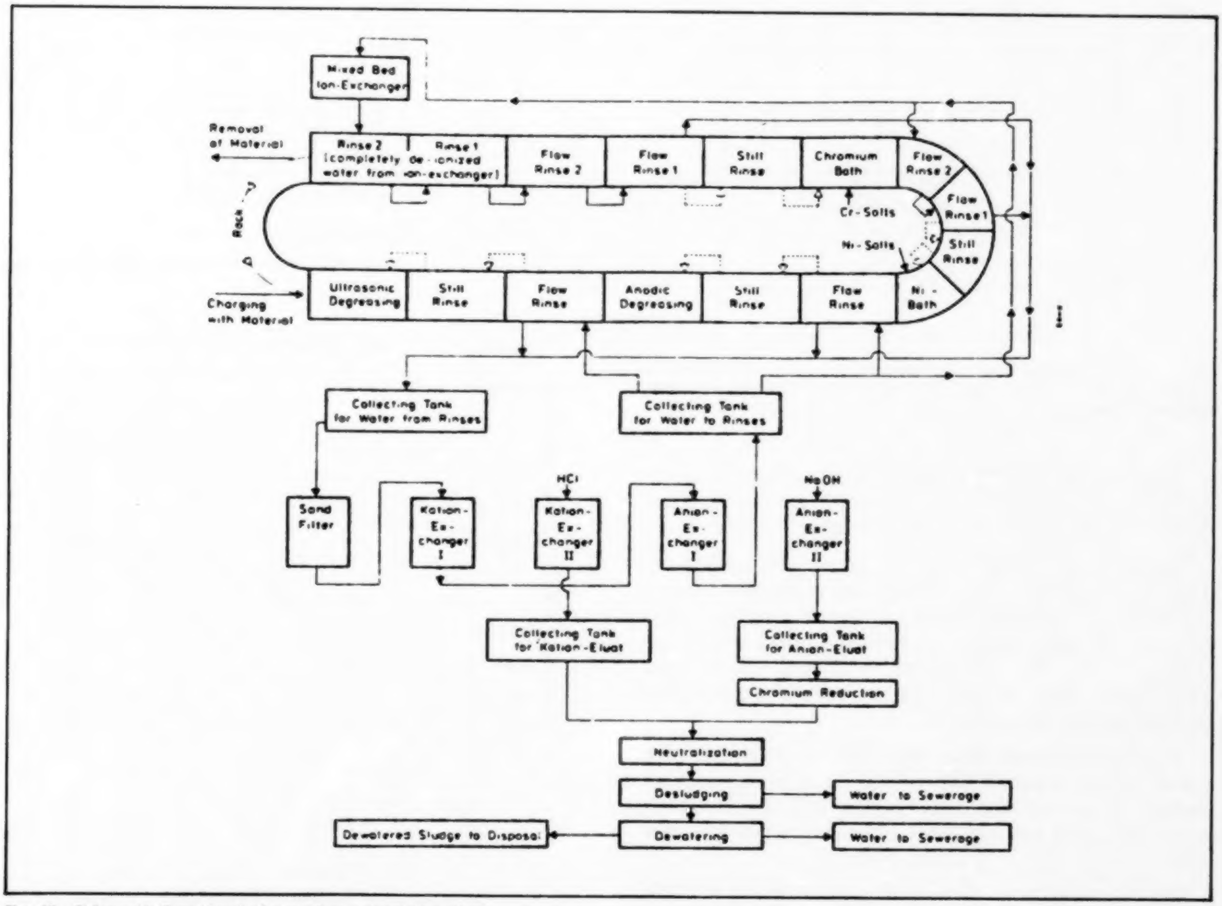
Mixed Bed Ion-Exchanger
Removal of Material
Rinse 2
Rinse 1
(completely de-ionized water from ion-exchanger)
Flow Rinse 2
Flow Rinse 1
Still Rinse
Chromium Bath
Flow Rinse 2
Flow Rinse 1
Still Rinse
Cr-Salts
Ni-Salts
Rack
Ultrasonic Degreasing
Still Rinse
Flow Rinse
Anodic Degreasing
Still Rinse
Flow Rinse
Ni-Bath
Charging with Material
Collecting Tank for Water from Rinses
Collecting Tank for Water to Rinses
HCl
NaOH
Sand Filter
Kation-Ex-changer I
Kation-Ex-changer II
Anion-Ex-changer I
Anion-Ex-changer II
Collecting Tank for Kation-Eluat
Collecting Tank for Anion-Eluat
Chromium Reduction
Neutralization
Desludging
Water to Sewerage
Dewatered Sludge to Disposal
Dewatering
Water to Sewerage

Fig. 13—Schematic flow-sheet of a modern galvanizing plant.

or concentration since, in general, inert industrial sludges, sandtrap residues and oily earth, if in appropriate quantities can safely be tipped on controlled domestic refuse dumps.

Special wastes are subdivided as follows:

- Materials such as oil-contaminated soil, tar residues, solidifying acid sludges and the like which, owing to their potential for air and water contamination, may be deposited at suitably prepared sites, subject to special precautions.
- Materials which can or must be disposed of by burning (e.g. solvents, used oil, oil wastes and residues, fullers' earth containing oil).
- Organic or inorganic materials which must receive chemical or physical treatment before being disposed of. These include: acids, alkaline solutions, sludges from the chemical and metal processing industries, and water-soluble heavy metal salts.

Before the materials are treated, a sample is examined in order to determine the type and effect of the process which is required and to check if the customer has marked the waste correctly. In general, treatment itself consists of one or more of the following processes:

- Neutralization and decontamination;
- Thickening and dewatering: chemical/mechanical/thermal;
- Purification of wastewater so that it can be discharged into a drainage system or receiving water course;
- Incineration
- Tipping, on domestic refuse tips/on specially prepared sites.

2. Bodies responsible for disposal of special wastes

In Bavaria, the problem of disposing of special wastes received attention at an early stage and it was found that, only a broadly-based solution made economic sense. owing to the technical and financial resources needed to build and operate the requisite plants, which had to satisfy the requirements of public health and order, particularly those concerning preventive measures against emissions and water pollution. The initial idea was to entrust the task to the bodies already engaged in the disposal of special wastes at regional levels and to extend this over the whole "Land," but it then became apparent that a joint body responsible for special waste disposal comprising public and local authorities and commercial firms would be the best solution in Bavaria.

Thus the end of 1970 saw the founding of the "Gesellschaft zur Beseitigung von Sondermull mbH (limited company for the disposal of special wastes), "GSB" for short, with a capital of DM 1 million, 40% of which was provided by the Bavarian authorities, 30% by the three leading local authorities and 30% by 25 firms from the chemical, metal processing, paper and oil industries in Bavaria. (By additions to capital in 1975, 1977 and 1979, the present sum is DM 20.93 million, the number of firms has now risen to 74, an increase of 49). The company's purpose is to dispose of or recover in a correct manner the special wastes arising in Bavaria and to engage in related activities. This serves the public interest and is not intended for profit.

The company, which operates as a private enterprise and is required only to cover its costs, is responsible for building and operating the installations needed for its work. In so doing, it must specialize in taking delivery of those wastes in which private waste disposal contractors generally have little interest because they are unprofitable, and must introduce and apply methods for the proper and economical disposal, processing or recovery of wastes specific to certain industries.

The fact that the GSB does not have to make a profit on waste disposal and that the supervisory board representing the members of the company has to approve the disposal charges means that conditions now exist which enable commercial and industrial concerns to deliver their wastes to the GSB and have them properly disposed of in accordance with the law, without the need for coercion. In this connection, the high public authority holding (over 75%) of the company's stock and the resulting priority given to safety provide a guarantee of optimum environmental protection in the building and operating of plants and in the treatment of materials. Companies modelled on the GSB, with a similar composition and identical aims and tasks, have now been set up.

The GSB began its work on 1 March 1971; firstly, an overall approach to the disposal of special waste in Bavaria was worked out and then the extension of existing plants and the construction of new facilities was planned and put in hand.

3. Disposal plants and collection sites

In view of the economic structure and the size of Bavaria, it is planned to establish three central treatment plants and a network of collection sites in areas where arisings of special wastes are greatest.

The disposal plants provide facilities for pretreating, incinerating and tipping wastes; they are equipped with dewatering, neutralization, detoxification and water purification plants, including sludge thickeners, filter presses and emulsion separators, as well as mixing installations and, finally, officially-approved landfill sites which are carefully operated to avoid odor emissions and whose waste water is collected in observation tanks for monitoring.

3.1 Schwabach disposal plant

This plant is run by the "Sweckverband Sondermullplatze Mittelfranken" (ZVSMM), which was set up in 1968 and disposes of special wastes in the administrative district of Middle Franconia. It is located conveniently near the Nuremberg Furth/Erlangen industrial zone and contains an incinerator plant with a capacity of 9 Gcal/h, a physicochemical treatment plant, a wastewater purification plant and an officially-approved landfill site with a capacity of 500,000 m^3.

3.1.1 Commitment

The industry in Middle Franconia has taken a favorable development during the last 20 years.

The large quantities of wastes occuring in this production sphere could not, due to the difficult character, be integrated into domestic refuse disposal.

This special department was thus established in 1966 and is dedicated to solving these problems in the common interest as a nonprofit organization.

The administrative association is a corporate body incorporated under public law.

3.1.2 Members of the Administrative Association

Members of the administrative association are: the cities of Ansbach, Erlangen, Fuerth, Nuernberg and Schwabach, not incorporated in a county; the counties of Ansbach, Erlangen-hoechstadt, Fuerth, Neustadt/Aisch-Bad Windsheim, Nuernberg rural area, Roth, Weibenburg-Bunzenhausen; the large county city of Weissenburg in Bavaria; the cities of Lauf a.d. Pegnitz, Roethenbach a.d. Pegnitz, Roth Stein; the community of Neunkirchen a.S.

3.1.3 Catchment - Area

The operational territory is the whole district of Middle Franconia.

The official catchment area covers in addition:

a) *in the district of Upper Franconia:* six counties and three cities, not incorporated in a county.

b) *in the district of the Upper-Pfalz:* three counties and one city, not incorporated in a county.

c) *in the federal state of Baden-Wuerttemberg:* eight counties.

Total Catchment area:

25,000 square kilometres =

10% of the area of the Federal Republic of Germany

3.1.4 Efficiency of the Schwabach treatment-complex

A composite unit comprising laboratory, landfill site, water treatment plants and incinerator, the Schwabach treatment-complex receives 110.000 tons of special wastes per year.

From this quantity, 40 percent are dumped in the specially-designed special wastes dump, 25% are treated in the decanting plant with an emulsion separating system, 20 percent are treated in the detoxication-neutralization-and dewatering plant and 15 percent are incinerated.

The working procedure at Schwabach is to put all loads received over the weighbridge on arrival, and to take a sample immediately. Analysis is normally completed within 10 minutes, and on the basis of this, the waste is directed to the incinerator, to the treatment plants or direct to the landfill site.

Where direct landfill disposal is not possible, oil and water are separated, so that the oil can be incinerated, while water is treated before discharge into a watercourse adjoining the site. Chemicals are treated and neutralized.

The sludge dewatering plant is able to handle sludge arising from galvanizing operations. After detoxification, dewatering and neutralization, the water obtained from press filtering must pass a recording pH meter check prior to being introduced into the public drains. The spadable filter cake can then be disposed of in the special wastes dump.

Until now over 5,000 experts from 29 countries have visited the Schwabach treatment-complex.

The treatment plant installed at Schwabach was taken as an example for similar plants in the Federal Republic of Germany and in foreign countries.

3.2. "Sud" disposal plant

The Sud disposal plant of the GSB, situated in the Munich/Augsburg/Ingolstadt area, consists of two associated sections constructed along the latest technical and economical lines; the first, consisting of mechanical facilities, is at Ebenhausen, near Ingolstadt, and the second, the Gallenbach landfill site for special wastes, is situated in the rural district of Alchach-Friedberg. The separation of the two sections, which lie about 40 km apart, is due to the difficulties now experienced in purchasing land for plants of this kind.

After much detailed planning and a relatively short construction period, the Sud disposal plant started operating at the beginning of 1979.

3.2.1 Ebenhausen mechanical installations

The Ebenhausen plant, built on a site about 4 hectares in area, contains the following: a general-purpose section with a vehicle weighing machine, a workshop and store-rooms; an administrative building housing offices, staff facilities and the fully-equipped central laboratory; an incinerator plant for liquid, semi-liquid and solid wastes; a physicochemical treatment plant for used alkaline solutions, used acids, plating sludges, inorganic sludges containing chromium, cyanide and nitrites; and a plant for purifying industrial wastewaters.

The incinerator plant on the eastern side of the site contains two rotary furnaces, a steam generator, and a highly-expensive flue gas purification plant consisting of electro-filters and two-stage flue gas scrubbing plant, a turbogenerator and all the requisite auxiliary installations. Its heat output is 25 Gcal/h - 12.5 Gcal/h from each of the rotary furnaces and the liquid burners.

In this way it is possible to operate simultaneously either two firing systems at full capacity or three systems at reduced capacity. The planning allows for the addition of a further unit of the same type.

The firing installations are followed by the large secondary combustion chamber in which the temperature is kept at a minimum of 1000° C. The flue gas is then cooled to about 280° C in a steam generator with exclusively smooth-walled pipes to inhibit sooting of the heating surfaces and a switchback configuration in order to increase the separation of solid constituents from the flue gas flow.

The flue gas cleaning system consists of an electro-filter for separating out fine dusts and a two-stage scrubbing plant for removing chlorine, fluorine and SO^2 from the flue gases. The scrubbing water is recirculated and is treated in the physicochemical plant.

The steam which is produced (32 t/h, 25 gauge atm.) is used both to produce electrical energy for the plant's own use and to heat the plant's installations. Surplus steam is condensed in an air-cooled heat exchanger to avoid polluting the environment. An oil-fired boiler with a large water space (6 Gcal/h) is available for supplying heat when the incinerator is out of operation.

The control room and the power supply installations such as switchgear, a transformer, a turbogenerator, a feedwater treatment plant and a boiler are housed in a central situated building. The receiving bunkers for solid and semi-liquid wastes and the loaders for the rotary furnaces are roofed in while all the remaining parts of the plant are in the open.

In the physicochemical treatment plant (CPA), situated in the western half of the site, the materials are put in one of the eleven 30 m^3 receiving tanks, depending on the results of the laboratory tests. These tanks lead into several storage tanks of the same capacity and, finally, these are followed by the individual treatment plants consisting of mixing and dosing units.

Any sludge which is produced is drained in chamber filter presses, the filter cakes are taken to be dumped and the filtrate as well as other waste water is discharged to the receiving watercourse or to a sewage treatment plant via final inspection points and retaining vessels.

Pollutants are removed by a gas scrubber to which the contaminated air and waste gases from the containers in the CPA are conveyed. The purification plant for industrial waste waters containing oil and emulsions (ARA), which is integrated into the CPA and has been developed by the GSB, consists of two tanks with a capacity of about 300 m^3, a centrifuge, a mixing and dosing unit, and a vacuum drum filter.

3.2.2 Gallenbach landfill site (Figure C)

The site, about 17 ha in area situated near the Munich-Stuttgart motorway on Federal highway No. 300 leading to Ingolstadt, is crossed by a layer of clay and loam between 8 and 18 m thick which prevents water from seeping into the lower groundwater table. Above this layer there are moraine deposits, gravel and sand, which are gradually being removed and used to construct each section of the site. In contrast to those collection sites for which existing trenches are usually chosen, here the earth pits have to be dug.

This produces a sufficient quantity of excavated material for covering purposes, such material often being difficult to obtain in other circumstances. Since the outer slopes are planted and grassed while the landfill site is being constructed, the appearance of the landscape is altered only for a relatively short time. The inner surface is covered with a clay/loam puddle layer at least 40 cm thick which acts as a sealing material. The leachate is received by drainage courses with a filter gravel base about 2 m beneath the pit bed and, like the surface water, is conveyed to three retention tanks with a total capacity of about 10,000 m^3. When a tank is full, the water in it is inspected and, if found to be in satisfactory condition , is discharged to the receiving watercourse. If it does not meet the discharge requirements, it is retreated and transported to a sewage treatment plant. The groundwater is continuously monitored by means of sampling tubes reaching down to the lower groundwater table.

The landfill site for special wastes has a gross storage capacity of about 1.5 million m^3 and will take about 15 to 20 years to fill. In addition, it includes an administrative building with an office, staff accommodation, a testing room, a shed for earth moving machinery and other vehicles, and a vehicle weighing machine.

The first section, completed in 1975 in only nine months, has a storage capacity of 450,000 m^3.

3.3 Schweinfurt disposal plant

The third disposal plant is situated in Schweinfurt. At present, it is an incinerator plant for industrial wastes which are similar to domestic refuse (heat output of about 9 Gcal/h) and was purchased by the GSB at the end of 1972 from the former "Sweckverband fur Abfallbeseitigung in der Stadt Schweinfurt" (association for waste disposal in Schweinfurt). Since then, further installations have been added so that it can receive further wastes.

In the long term, it is planned to replace the present plant with an incinerator plant for liquid and semi-liquid wastes (with the same heat output of 9 Gcal/h).

3.4 Collection sites

The collection sites for special wastes, where various wastes from nearby firms - often in small quantities - are delivered and temporarily stored, help among other things to reduce transport costs (an important factor in view of the size of Bavaria, which covers one third of the area of the Federal Republic) by the combination and use of convenient bulk transport vehicles and by the existence of a standard list of charges for the whole Land in order that firms situated outside the main industrial centres should not be placed at a disadvantage.

The collection sites are designed on uniform lines and generally contain the same equipment. Apart from the temporary storage of waste, they are also responsible for pretreating as much waste as possible and for reducing its volume with the aid of easily-operated technical installations. They contain waste water purification plants (ARA), in which the consistently large quantities of oil/water mixtures that are delivered are separated out into oil, water and solid matter. The purified waste water is immediately drained off. What remains, less than 10% of the original amount, is in the form of an oily sludge which is then transported elsewhere.

When justified it is planned to install neutralization and, if necessary, sludge thickening equipment. Furthermore, in addition to an administrative building with a testing room and a vehicle weighing machine, all collection sites have adequate storage space for oil-contaminated earth and for freight containers designed to collect and temporarily store industrial sludges of all kind.

Collection sites already exist in Aschaffenburg, Augsburg, Mitterteich, Munich, Neu-Ulm, Passau and Straubing. Within the next few years it is planned to construct further collection sites in Bamberg and Kempten and a new large-scale site in Munich.

The GSB keeps in close contact with all the organizations which are concerned with the planning of new disposal plants for domestic refuse or sewage sludge in order that new plants (incinerators and landfill sites) are, wherever possible, designed and constructed from the outset so that they can dispose of special wastes. Thus, for example, oily sludge with a high calorific value which is brought to the collection site is ideally suited to back up the burning of sewage sludge, a process which will become increasingly important in the future. In Neu-Ulm, combined operation of this kind between a collection site and the incinerator unit of a neighboring sewage treatment plant is already taking place. Efforts are also in hand to set up a joint operation between the collection sites and domestic refuse incineration plants which are to be built in Bamberg and Kempten, in order that part of the wastes can be disposed of on the spot.

4. Recovery plants

At the Ebenhausen incinerator plant, heat and electric power (for the plant's own use) are derived from the wastes and converted into usable form. The incineration of wastes with a high calorific value which occurs in Sohweinfurt is also of benefit since it enables non-combustible materials to be disposed of more efficiently and at less cost.

As a result of the recognition that raw materials have to be used more sparingly in future, the main emphasis in waste disposal is shifting increasingly to recovery and reutilization.

This led the GSB, at the end of 1973, to take various steps, including the purchase of a firm situated at Gereteried, near Munich, which was engaged in the distillation of used solvents, varnish thinners, degreasing agents and similar materials, to ensure that the recycled materials were put back on the market.

5. Deliveries and transport

Disposal of special wastes can be effective only when these materials are clearly described and when their transport is supervised. To this end, in addition to the form specified by the authorities, the GSB also issues numbered forms consisting of several sections which must be completed and officially signed by the producer (or originator) of the waste. When the waste is handed over to a haulier, the customer retains one copy of the form as a receipt whilst the remaining copies, the contract and the confirmation of the contract are delivered along with the wastes to one of the GSB's offices; the hauler retains the other copy which enables him to present a bill for his services. Before the vehicle is emptied, the details given by the customer are checked, as is the amount (by weighing) and the description of the materials are checked by means of the serial numbers on the forms which have been issued. The costs of disposal incurred by the GSB are charged directly to the producer of the waste; normally the GSB does not accept orders for waste disposal from haulers. The GSB also refuses to accept delivery if the form is not properly completed or if the conditions under which delivery is accepted have not been observed.

The transport of special wastes falls into two categories; the delivery to the collection site (the "collection service") and the conveying of the wastes by bulk transporters from the collection site to the disposal plant.

The "collection service" is generally performed by efficient and reliable private haulage firms which, when the customer does not make the delivery himself, also represent a guarantee that the wastes will arrive at the collection site. Bulk transport between the collection site and the disposal plant is normally carried out in freight containers or tankers in cooperation once again with private hauliers.

6. Amounts of waste received and capital expenditure

The growth of the GSB over the last few years can be seen from the following figures on deliveries of special wastes:

Year:	1972	1973	1974	1975	1976	1977	1978
Amount:	60	116.5	134	165	171.6	186.4	183.1

Last year the GSB and the ZVSMM duly disposed of a total of 300,000 t of special wastes in Bavaria.

By the end of 1978, the construction of the abovementioned installations had cost about DM 80 million, towards which the Bavarian authorities contributed generous "Land" grants and low-interest government loans.

SUMMARY

In this paper I have attempted to outline in examples the treatment being used for different wastes from the metal finishing and other industries.

I hope that those who are struggling with the same problem will find this description useful.

EPA's Centralized Treatment Program

Alfred B. Craig, Jr., and George C. Cushnie Jr.*

INTRODUCTION

The Metal Finishing Industry utilizes more than 100 surface finishing and fabricating operations that require aqueous application and removal of various metals to and from metallic and plastic parts. The metal finishing process baths contain various cyanides and cyanide complexes, hexavalent chrome, copper, nickel, zinc, cadmium, and other metals that must be disposed of once the end of the useful life of the bath has been reached. In addition, water used to rinse plated parts contains dilute concentrations of these metals.

A vast majority of electroplating shops reside in large industrial communities in and around municipalities. A majority of the plants in the electroplating industry discharge untreated or lightly treated rinse water and plating baths to municipalities for treatment by Publicly Owned Treatment Works (POTW's). These nonbiodegradable pollutants are discharged in millions of gallons of process water each day to biological treatment systems, which are ineffective for treating such wastes.

Impacts of Metal Finishing Operations on Publicly Owned Treatment Works

Pollutants in metal finishing process wastewater interfere with proper operation of biological systems and restrict the utilization of biological sludges because of their high metal content. Cadmium, chromium, lead, nickel, and zinc are not destroyed when introduced into a POTW and will either pass through the system or will contaminate the sewage sludge. The metal content of this sludge may preclude land application of sewage sludge on food crops; sewage sludge disposal by incineration is also questionable because of the volatility of cadmium and lead.

The Enabling Regulations

The Environmental Protection Agency is currently proposing and promulgating a series of industrial wastewater pretreatment regulations. These regulations will reduce the introduction of industrial wastewater pollutant parameters to POTW's. In order to comply with these pretreatment regulations, indirect dischargers will be required to install various process wastewater control and treatment technologies at their plant sites. These regulations, will cause adverse economic impact on some industries and some small plants with limited personnel and capital for addressing these regulations undoubtedly will be forced to close.

Simultaneously, EPA is implementing Congress' intent of the Resource Conservation and Recovery Act (RCRA). Industry, in complying with the provisions of RCRA, will be required to safely dispose of their residual wastes. The cost of waste disposal and management will likely increase as will administrative burdens associated with the proposed waste management system.

Research on Centralized Treatment

Three years ago, EPA's Office of Research and Development (ORD), anticipated the potential impact to industry resulting from compliance to pending wastewater and solid waste regulations. Therefore, it began investigating conceptual alternatives to on-site industrial waste treatment by generators. One promising alternative is centralized treatment. The primary assests of this approach are scale economy and improved waste management. Centralized treatment provides experienced management and personnel whose primary responsibility is in handling wastewater and solid waste residuals; this contrasts with production personnel who can provide only intermittent supervision of treatment practices at individual industrial plant sites.

ORD has taken an active role in investigating the Centralized Waste Treatment (CWT) concept, determining its applicability to the metal finishing industry, and laying the groundwork for implementation. An ORD project in 1977 established the economic feasibility of a joint waste treatment plant and investigated the legal and institutional arrangements necessary for successful implementation and operation. In 1978, ORD sponsored a second project that investigated the successful centralized treatment application in the Ruhr Valley in Germany. This same project explored the applicability of CWT to the United States taking into account U.S. costs and U.S. environmental requirements.

In June of 1979, a third project was funded by ORD. This project, which will be completed within 3 months, has developed the background information for industry implementation of centralized treatment. A manual describing technical, economic and financial aspects will be issued in July. The remainder of this paper will be devoted to the current EPA Centralized Treatment Program effort. An explanation of project objectives and procedures and a summary of available results will be presented.

CWT PROJECT OBJECTIVES AND OVERVIEW

The current project is divided into two phases. The purpose of Phase I is to determine the conditions that are favorable to CWT development and to identify which areas of the U.S. meet these conditions.

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The first task of Phase I comprised a categorization process that defined characteristics that affected the feasibility and design of a CWT system. Then, five case studies were chosen to represent varying situations in which CWT would be applicable. To determine the feasibility of CWT in each of the case study areas, data were gathered from municipal, regional, and industrial sources, and an analysis was performed.

The purpose of Phase II was to develop and demonstrate the approach necessary for implementation of central treatment. This was accomplished by selecting one promising area and developing a comprehensive metal finishing waste control plan that includes a CWT system configuration with collection, transportation, treatment and disposal; on-site treatment requirements; financing requirements and alternatives; and management options.

Phase I - Categorization and CWT Feasibility Case Studies

The activities of Phase I were focused on the selection and analysis of the five case study areas. The procedure for Phase I included six major tasks:

- Categorization of U.S. metropolitan areas containing a substantial metal finishing population
- Selection of 24 metropolitan areas for case study consideration
- Selection of five case study areas
- Data collection and characterization of case study areas
- Development of analytical tools
- Case study analysis of CWT feasibility

Categorization of U.S. Metropolitan Areas Containing Substantial Metal Finishing Population

A statistical categorization process was used in Phase I so that the results of the five case studies could be applied to a major portion of the metal finishing industry across the U.S. within characteristic regions. The basic premise behind this categorization was that if a case study had a feasible solution for CWT, then all cities in the same

Table 1
Factors for Developing Categorization

Factors Affecting Feasibility and Design of CWT	*Probable Effect of Factor*
GOVERNMENTAL FACTORS	
• Willingness of Municipalities to Participate in CWT	Participation and cooperation by municipal governments will hasten the implementation of CWT; however, a strong private interest in CWT may overcome municipal barriers.
• Future Plans of Municipality with Respect to Industrial Discharges	Municipalities with immediate plans to enforce pretreatment will reduce feasibility of CWT.
• Availability of Disposal Sites	CWT is more likely to be feasible in localities containing disposal sites.
• Number of Local Governments Involved	A large number of local governments will present a less feasible situation, since jurisdictional disputes will be a barrier to CWT. If a league of cities exists, the effect of this factor may be mitigated.
• Non-Federal Regulations	Local pretreatment regulations may have already precluded CWT by forcing individual treatment to be presently installed.
• Type of Municipal Government	Various types of municipal government structures should be investigated. At this time, the effect of this factor is uncertain.
• Municipal Willingness to Fund CTF	Municipal funding may be necessary in certain areas; however, private funding may eliminate the effect of this factor.
• Municipal Financial Conditions	Some cities may qualify for Federal assistance in constructing a central treatment facility (CTF). Some cities may be able to affort CTF or be able to raise money through bonding.
• Municipal Demography	Population size and density will affect the availability of land for CTF and disposal siting. Also, cities with a high population concentration may have traffic congestion that increases hauling time and, therefore, CWT costs.
INDUSTRIAL FACTORS	
• Number of Metal Finishing Plants	The number of plants may affect the design of the CTF. Also, larger numbers of facilities will favor CWT.
• Concentration of Metal Finishing Facilities	Higher concentrations of facilities will favor CWT.
• Willingness of Metal Finishing Industry to Participate in CWT	Without the minimum number of customers required to reach economies of scale, CWT will not be feasible.
• Total Wastewater Flow	Minimum flow needed for feasibility of CWT.
• Present Treatment Installations	Installed treatment facilities may preclude CWT.
• Future Plans of Metal Finishing Industry	Immediate plans to install pretreatment may preclude CWT.
• Types of Waste	The type of waste affects the design of the CTF. Also, CWT is most amenable to concentrated metal-bearing wastes.
• Types of Metal Finishing Industry	The type of industry affects the waste characteristics and, therefore, the design of the CTF and feasibility of CWT.
GEOGRAPHIC FACTORS	
• Regional Location	Most segments of the metal finishing industry are unevenly distributed. For example, the jewelry industry is concentrated in the Northeast, and the electronics industry is in the Southwest and Far West. This factor will affect the design and feasibility of CWT.

category should result in a similarly feasible CWT scheme.

The initial step in developing the categorization scheme was the identification of factors that were expected to affect the feasibility and design of a CWT system. These factors are listed in Table 1. The next step was to develop quantifiable categories utilizing the factors. A simple solution to categorization would have been to designate each metropolitan area as a category. This could be done easily, since all possible combinations or permutations of the various factors would produce a very large number of potential categories. This, however, would defeat the purpose of categorization, since results from one municipality could not be applied to others.

To avoid the problem of too many categories, four major factors were used to define the initial categorization scheme (Table 2).

Table 2
Municipal Categorization Scheme

Category 1	*Category 2*	*Category 3*
Bridgeport Hartford Att/Taunton Syracuse	Rochester Erie Baltimore Worcester Springfield Buffalo Pittsburgh	Trenton Silver Spring Camden Manchester Allentown Arlington Reading/Lancaster Harrisburg Long Island
Category 4	*Category 5*	
Providence	Boston Philadelphia New York Newark	
Category 6	*Category 7*	*Category 8*
Atlanta Miami New Orleans San Antonio Orlando	Houston Dallas/Ft. Worth	Canton Ann Arbor Kalamazoo South Bend
Category 9	*Category 10*	*Category 11*
Milwaukee Cincinnati Grand Rapids St. Louis Indianapolis	Tulsa Kansas City Toledo Columbus Oklahoma City Rockford Ft. Wayne	Chicago Cleveland Detroit Minneapolis/St. Paul
Category 12	*Category 13*	*Category 14*
San Francisco Los Angeles Fullerton	Seattle Denver Alburquerque San Diego Portland Honolulu Phoenix	San Jose Riverside Ontario Santa Barbara

These major factors include:

- Number of local governments
- Municipal demography
- Number of metal finishing facilities
- Regional location

Aside from their relative importance, these particular factors are closely related to the other factors identified in the categorization step; therefore, the resultant categorization scheme actually encompasses a broad range of factors. For example, the regional location of a metropolitan area is closely related to the type of industry and the type of waste since particular segments of the metal finishing industry tend to concentrate in particular regions. Similarly, the number of metal finishing facilities is closely related to the concentration of metal finishing facilities.

Selection of 24 Metropolitan Areas for Case Study Consideration

In the selection process, it was assumed that the best choice of metropolitan areas would be those where a need exists and where municipal cooperation can be expected. Also, it was believed that all EPA Regions should be involved in the next stage of the CWT project. To satisfy these assumptions, the following criteria were used in the selection process:

- Choose all localities that have shown a willingness to participate in a CWT project
- Choose mostly metropolitan areas with a large number of metal finishing facilities
- Exclude localities that have pretreatment programs with stringent regulations for the metal finishing industry. (If stringent local pretreatment regulations were currently in effect, it might preclude the establishment of a central treatment facility since plants may already have committed to individual waste treatment.)
- Choose localities with a relatively small ratio of population to number of electroplaters. (This is a simplified measure of the economic dependence of a particular area on its metal finishing industry.)
- Choose at least one metropolitan area per category.
- Choose at least one locality per EPA Region.

The selection process resulted in the choice of 24 metropolitan areas. These are listed in Table 3.

Table 3
Metropolitan Areas Chosen for Further Study

Category	*Metropolitan Areas*
1	Bridgeport
2	Rochester
2	Erie
3	Trenton
4	Providence
5	Boston
5	Philadelphia
6	Atlanta
6	Miami
7	Houston
7	Dallas/Ft. Worth
8	Canton
9	Milwaukee
9	Cincinnati
2	Buffalo
10	Tulsa
10	Kansas City
11	Chicago
11	Cleveland
12	San Francisco
13	Seattle
13	Denver
13	Albuquerque
14	San Jose

Selection of Five Case Study Areas

The first step in the selection process was to formulate a group of criteria that reflects the desired qualities of a case study area. These criteria included technical, economic, political, and administrative considerations (Table 4). The 24 candidate case study areas were then visited to collect information related to each of the criterion.

The actual selection was performed by using a decision process that quantitatively evaluated how well each candidate area satisfied the various criteria. Those areas that were best suited to the decision criteria were then selected.

The decision technique that was utilized is termed worth assessment. With this method, an analytical model is developed that allows any number of decision criteria to be used in a selection process. The criteria are quantitatively weighed (0 to 1, with the total weights of all criteria equaling 1) to reflect their intended importance in the decision. Then, for each candidate, a worth assessment score is calculated by: (1) evaluating or scoring on a scale of 0 to 1 how well each candidate locality satisfies each criterion, (2) multiplying the score for each criterion by its weighted value, and (3) summing over all criteria.

Several criteria, such as municipal cooperation, were given overriding consideration because they could limit the success of this project and CWT for that region. Therefore when certain constraint criteria were not satisfied, the entire worth assessment score for that particular locality was assigned a value of zero.

The worth assessment exercise resulted in the scores and case study selections shown in Table 5. As indicated in Table 5, the metropolitan area of Philadelphia was chosen although both Denver and Buffalo scored higher in the analysis. This was done because of the small difference in scores and the fact that the categories (Table 2) which contain Denver and Buffalo would already be represented by Seattle and Milwaukee, respectively, which had been likewise chosen.

Data Collection and Characterization of Case Study Areas

The data necessary to evaluate the feasibility and design of CWT was collected via visits to municipal and regional authorities, such as POTW's, in each of the case study areas and through the use of an industrial survey.

The basic philosophy used in data collection was to first gather as much available information as possible from municipal and regional authorities.[*] The additional data necessary for a feasibility analysis was collected from industry via an industrial survey. The survey was distributed to metal finishing companies in the five case study areas by the American Electroplaters' Society (AES). Once completed and returned to AES the survey responses were forwarded to the centralized treatment study project team to be compiled and used for the feasibility analysis.

Information and data from local governments and industry were combined to characterize each of the case study areas. All metal finishing facilities which discharge wastewaters were mapped along with potential central waste treatment sites and landfills. Effluent data and information concerning installed waste reduction or treatment equipment for each metal finishing facility were compiled. Transportation routes were defined for shipping wastewaters and sludges from metal finishing plants to the potential central sites and the landfills.

Development of Analytical Tools

A mathematical model was developed to evaluate the feasibility of CWT and to determine the configuration of

Table 4
Case Study Selection Criteria

	Area of Impact			
Criteria	*Technical*	*Economic*	*Political*	*Project Administration*
Municipal Cooperation with Project Personnel	●			●
Present Local Pretreatment Regulations	●		●	
Availability of Disposal Sites	●			●
Number of Municipalities in Metropolitan Area			●	●
Number of Sewer Authorities in Metropolitan Area			●	●
Local Plans for Enforcing Future Regulations	●		●	
Economic Impact (Ratio of Population to Number of Metal Finishing Companies		●		
Concentration of Metal Finishing Companies	●	●		●
Current Availability of Central Waste Treatment	●	●		
Number of Metal Finishing Companies in Metropolitan Area	●	●		●

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[*] Government sources were generally able to supply the following types of pertinent data and information: metal finishing shop location, water use and effluent concentrations for metal finishing facilities discharging to POTW's; location and ownership of landfills accepting metal bearing sludges; and location, size, and zoning classification of land tracts that could serve as sites for a centralized treatment facility.

Table 5
Worth Assessment Scores For Case Study Analysis

*Milwaukee	0.684
*Seattle	0.639
*Cleveland	0.638
*Atlanta	0.634
Denver	0.634
Buffalo	0.622
*Philadelphia	0.618
Trenton	0.574
Miami	0.532
San Francisco	0.532
Erie	0.503
Tulsa	0.503
Chicago	0.444
Dallas/Ft. Worth	0.418
Canton	0.404
Kansas City	0.398
Boston	0.342
Rochester	0.325
Cincinnati	0.300
Houston	0.286
San Jose	0.
Albuquerque	0.

*Areas Selected

a CWT system for each of the case studies. The model is capable of simulating cost effective alternatives for given scenarios considering various options involving in-plant flow reduction, waste concentration, on-site treatment, and shipment to a centralized treatment plant.

The model was programmed in the efficient-structured language, Pascal, with the intention of using a microcomputer for the analysis. Descriptions of the model components, data input procedure, and logic flow follows.

Technical Basis of Computer Model

The model considers three typical raw waste streams generated by the metal finishing industry:

- Rinse waters and spent baths containing chrome
- Rinse waters and spent baths containing cyanide
- Other acid/alkali rinse waters and spent baths

It is assumed that these wastewaters are segregated into discrete streams to allow for separate treatment of chrome and cyanide.

Rinsing operations account for over 90 percent of water used by a typical plating facility; however, this water use can be drastically reduced through the installation of efficient rinse techniques such as countercurrent rinses, series rinses, spray rinses, and still or dead rinses. A reduction in water use will benefit shops by reducing the necessary capacity of waste treatment processes or the amount of wastewater to be hauled to a Central Treatment Facility (CTF).

To reflect the potential application of flow reduction, the model is programmed to consider the cost effectiveness of converting single running rinses to two-stage countercurrent rinses. Other techniques, such as dead rinses or ion exchange could also be used for concentrating rinsewaters; however, for this first analysis only countercurrent rinsing was considered. The use of other techniques will be investigated during latter stages of the project.

The cost of converting to countercurrent rinsing is assumed to be $3,000 based on the addition of a 5-foot by 6-foot by 4-foot tank, the appropriate plumbing, and an air agitation system. The countercurrent system is assumed to reduce the original single running rinse water use by greater than 90 percent.

Many shops will be unable to install an additional rinse tank because of space limitations or the use of programmed hoist lines. In these cases, it is assumed there is no potential for substantial flow reduction.

It is also possible for many shops to reduce rinse water usage through inexpensive, good water conservation measures such as flow control valves. During the course of the study, it was observed that most shops are using much more than is necessary to protect product quality; therefore, an additional factor was considered in the modeling exercise to account for these types of water conservation. It was assumed that tanks without flow control valves would reduce flow by 50 percent with minimal capital costs.

Conventional technologies were considered for treatment of wastes.* These technologies could be used either on-site or at the CTF. The possible waste treatment processes included:

- Chrome reduction
- Cyanide oxidation
- Physical/chemical treatment
- Sludge dewatering
- Storage (on-site only, to be used for plant selecting CWT options)

Waste streams with a chrome concentration above the 1982 pretreatment standards (Table 6) would be subject to chrome reduction. Similarly, wastewaters not complying with cyanide pretreatment standards would be subject to cyanide oxidation. The effluents from both of these treatment processes then would be combined with other acid/alkali wastes containing metals for physical/chemical treatment and sludge dewatering. A flow diagram of the typical treatment system is shown in Figure 1.

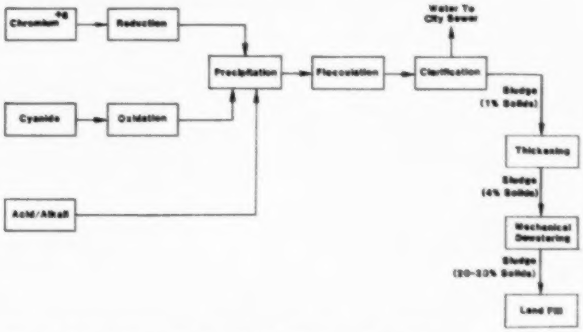

Fig. 1—Conventional Treatment Technology Flow Diagram.

Shops that would decide to use CWT for one or more waste streams would need to install enough storage tanks to accommodate the various wastes separately. Therefore, within the model, storage was costed as a treatment technology. It was assumed that the storage capacity would be large enough to contain at least one day's waste flow. The equipment considered in the cost of storage were 5,000 gallon tanks ($6,000 per tank, 1978 prices).

The analytical model was formulated to consider five waste treatment alternatives (Figure 2) which involve on-site treatment and/or hauling waste (via truck) to and treating at a CTF.

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*Recovery technologies are a viable alternative; however, they were not considered in this analysis.

Table 6
1982 Pretreatment Standards*
(mg/l)

Pollutant	*Average of Daily Values for 30 Consecutive Monitoring Days Shall Not Exceed*
CN (T)	0.23
Cu	1.8
Ni	1.8
Cr (T)	2.5
Zn	1.8
Pb	0.3
Cd	0.5
Total Metals	5.0

*These standards appeared in the Federal Register (Vol. 44, No. 175) on September 7, 1979. The standards have since been revised; however, the CWT analysis was performed before the changes were instituted and, therefore, are not reflected in this analysis.

In Option 1, the shop does not discharge contaminated process waters to the municipal sewer system. The concentrated rinse waters and batch dumps for all waste streams are hauled to a central waste facility for treatment. The sludge from waste treatment is dewatered at the CTF to approximately 20 percent solids and is hauled to a landfill.

Shops that select Option 2 would treat the cyanide and acid/alkali waste streams in-house (CN destruction, pH adjustment/precipitation) and send the dilute waste treatment sludge (approximately 4 percent solids) and raw chromium waste stream to a CTF. The CTF would properly treat the chromium waste stream, dewater the sludge, and haul the solids to a landfill.

Option 3 is similar to Option 2 except that the chromium and acid/alkali waste streams are treated in-house and the cyanide waste stream and sludge are hauled to a CTF.

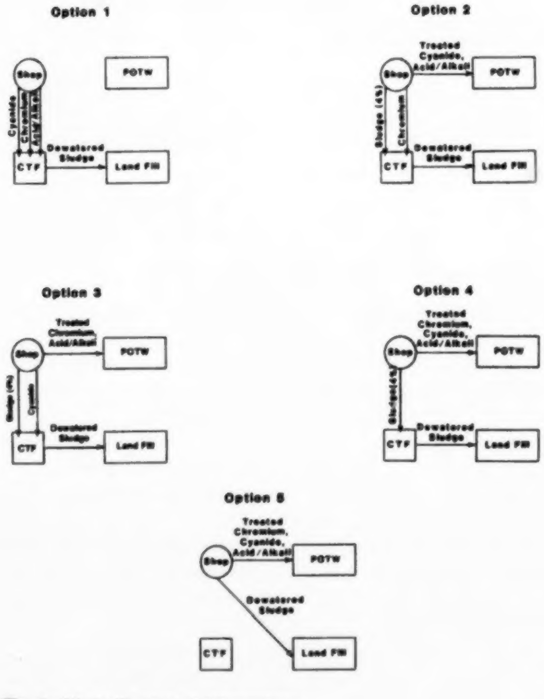
Option 1
Shop
POTW
Cyanide
Chromium
Acid/Alkali
Dewatered Sludge
CTF
Land Fill
Option 2
Treated Cyanide, Acid/Alkali
Shop
POTW
Sludge (4%)
Chromium
Dewatered Sludge
CTF
Land Fill
Option 3
Treated Chromium, Acid/Alkali
Shop
POTW
Sludge (4%)
Cyanide
Dewatered Sludge
CTF
Land Fill
Option 4
Treated Chromium, Cyanide, Acid/Alkali
Shop
POTW
Sludge (4%)
Dewatered Sludge
CTF
Land Fill
Option 5
Treated Chromium, Cyanide, Acid/Alkali
Shop
POTW
Dewatered Sludge
CTF
Land Fill

Fig. 2—Waste Treatment Alternatives

In Option 4, the shop chooses to treat all waste streams in-house and to send only the dilute sludge (4 percent) to the CTF for dewatering.

Under Option 5, the shop is not utilizing the CTF. Instead, all waste treatment and sludge dewatering is done in-house.

A summary of in-plant processes that would be performed by individual companies under each option in shown in Table 7.

Data Input and Computer Logic Flow

The information needed to run the model includes:

- Locations of each company and CTF site that are determined by using a grided map
- Volumes (gallons/day) and pollutant concentrations (mg/l) of the three waste streams (i.e., cyanide, chromium, and acid/alkali)
- Number of daily operating hours and days per year for each shop
- Total number of rinses for each shop and the number of rinses with flow reduction installed and with a potential for flow reduction.
- Local waste hauling costs ($/mile/5000 gallons)
- Interest rates
- Expected return on investment for industry
- Cost indexes (wholesale price index for chemicals, operating cost index, and chemical engineering plant cost index)
- Estimated lifetime of equipment
- Local electric power costs
- Assumed days of operation per year of the CTF

Table 7
In-Plant Processes for Each Waste Stream Under Each Option

	Stream			
*Option**	*Chromium*	*Cyanide*	*Acid/Alkali*	*Sludge*
1	5	5	5	-
2	5	2-3-5	3-5	5
3	1-3-5	5	3-5	5
4	1-3-5	2-3-5	3-5	5
5	1-2-4-5	2-3-4-5	3-4-5	-

*Process 1 - Chrome reduction
Process 2 - Cyanide oxidation
Process 3 - Physical/chemical treatment
Process 4 - Sludge dewatering
process 5 - Storage
Process 5 - Storage

The model proceeds in an iterative manner to converge on a solution using the following logic flow. On the first iteration, a CTF is sized assuming all wastes are sent to the CTF. The CTF is a maximum size after the first iteration, and therefore the cost for using CWT is the least possible because of economics of scale. In the second iteration, the model selects the least-cost option for each shop. Since the least-cost option for some companies may be to treat a portion or all of their wastes in-house, the size of the CTF at the end of the second iteration may have decreased. A decrease in size will cause user fees to increase because of a loss in economics of scale. If after the second iteration, there was a change of 5 percent or less in the size of the CTF, the model will assume convergence and will stop with that solution. If the change was greater than 5 percent, the model would continue iterations until it converges on a solution.

CASE STUDIES

As discussed, five metropolitan areas were selected for case studies. A preliminary analysis has been performed for each area using the microcomputer model, and results will be discussed in this paper. In an attempt to keep the discussion to a manageable size but to retain a comprehensive view of the study, a detailed analysis is presented for only one area (Cleveland) and the remaining areas are treated with a more general approach.

Cleveland Analysis

Data were collected from various sources for approximately 140 metal finishing shops in the Cleveland metropolitan area. From available information, it was concluded that 103 of these shops were not currently meeting 1982 pretreatment standards. These 103 shops were considered in the analysis. The current water use statistics for these shops are summarized in Figure 3.

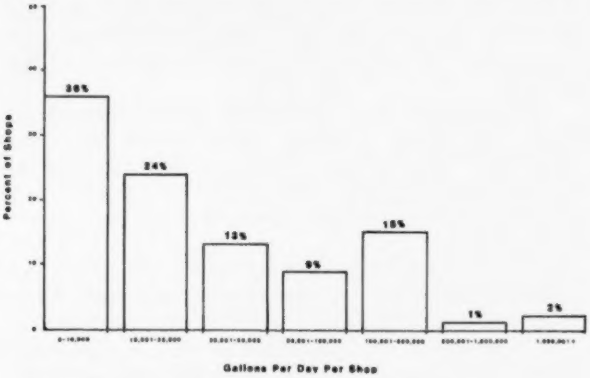

Fig. 3—Distribution of Cleveland Water Use Flow Rates

As shown in Figure 4, the majority of the 103 shops are clustered in a 50-square-mile area, and approximately 15 shops are located to the northeast in a second cluster. The potential CTF site is located in the southeast sector of the larger cluster. The mean distance between all shops and the potential CTF site is 7.8 miles. The nearest potential customer is located 0.5 miles from the central site, and the farthest company is located 29.9 miles from the site. A summary of major input parameters is provided in Appendix A.

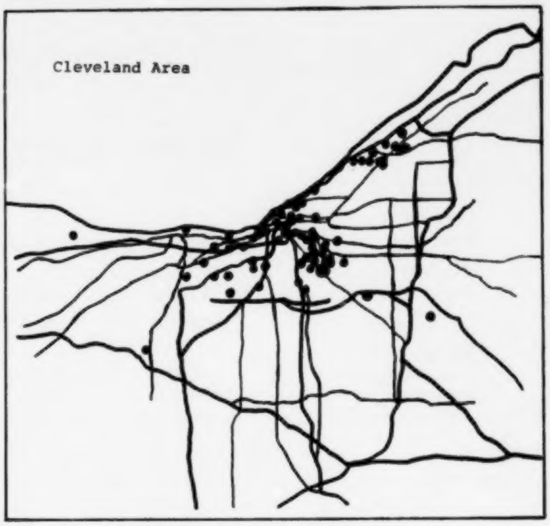

Fig. 4—Metal Finishing Shops in Cleveland Area.

The most economical waste treatment scheme determined by the analysis considering in-plant treatment and CWT is shown in Table 8. The annual costs associated with this configuration are presented in Table 9. The necessary processing capacities of the CTF components are shown in Table 10.

The Cleveland results show a very high percentage of participation in the CWT system. Only one of the 103 shops has not selected to use the CTF. That particular shop is located 19.5 miles from the CTF site and has a waste stream flow of 43,200 gpd after flow reduction.

For the vast majority of the small (less than 10,000 gpd before flow reduction) and medium shops (10,000 to 50,000 gpd before flow reduction) the program selected Option 1 (i.e., sending all wastes to the CTF) regardless of distance from the central facility. The distance was, however, a factor regarding the degree of flow reduction used. In general, as the distance increased from the central facility to the shops, the shops were more likely to install counter-current rinses. The average distance to the

Table 8
Most Economical Waste Treatment Scheme
For Cleveland Region

Option	*Number of Shops*
1 - All waste to CTF	86
2 - Chrome waste and all sludge to CTF	1
3 - Cyanide waste and all sludge to CTF	0
4 - Sludge only to CTF	15
5 - Nothing to CTF	1

Table 9
Regional Summary - Cleveland
(Annual Costs in Thousands of 1980 Dollars)

	Total Plant Investment	*Total Plant Operating Costs*	*Total Plant Chemical Costs*	*Total Plant Costs*	*Total Transport Costs*	*Total CTF Fees*	*Total Regional Costs*
W/o CTF	1,926	1,745	528	4,199	0	0	4,199
With CTF	345	297	247	899	1,129	486	2,504
Savings	1,581	1,448	281	3,310	-1,129	-486	1,695

Table 10
Processing Capacities and Costs of CTF Components
(All Costs in 1980 Dollars)

Process	*Required Capacity GPD*	*Annual Investment $ (1980)*	*Annual Operating Cost $ (1980)*	*Annual Chemical Costs $ (1980)*	*Total Annual Costs $ (1980)*	*Fee Rate $/Gal*
Chromium Reduction	40,700	7,200	3,800	11,400	22,400	0.0018
Cyanide Oxidation	41,000	17,800	6,100	240,600	264,500	0.0215
Precipitation	190,000	36,100	15,600	64,300	116,000	0.0020
Sludge Dewatering	3,646	19,000	6,500	0	25,500	0.0233
Storage	190,100	58,200	0	0	58,200	0.001

CTF for shops that decided to add counter-current rinses on all single overflow rinses (with potential for counter-current) was 9.3 miles. The average distance for shops that decided not to install counter-current for all potential rinses was 3.7 miles.

For better understanding of the analysis and the interpretation of the results, it will be most profitable to look at two typical plants (F1 and E6) in detail. F1 is an electroplating shop that works mostly with electric switch and outlet boxes. Aside from electroplating, the shop also performs degreasing/cleaning, pickling, and bright dipping. The shop has a combined waste flow of 18,500 gpd. It operates 11 hours per day for 250 days per year. The shop is located 6 miles from the CTF site.

F1 has no pretreatment equipment. The final wastewater discharge analysis (Table 11) indicates a need for cyanide oxidation and heavy metal precipitation.

Currently, F1 has a good housekeeping program. It has installed flow control valves (5 gpm) on all seven of its overflow rinses. Fl presently has no counter-current rinses, but all rinses have that potential. If waste streams (Cr, CN, and acid/alkali) were segregated into discrete flows, the individual discharges following countercurrent rinse installation for Fl would be:

	gpd
Cr waste stream	0
CN waste stream	7380
Acid/alkali waste stream	9225

Table 11
Analysis of Final Effluent - Shop Fl

Flow	18,500 gpd
Cr (+6)	< 0.1 mg/l
Cr (total)	0.3 mg/l
Zn	53.5 mg/l
CN	12.2 mg/l
Fe	6.8 mg/l

As a part of the total analysis for Cleveland, the computer program selected Option 1 (send all waste streams to CTF) as the least cost alternative for Shop Fl. Also, the results indicated that counter-current rinses should be installed at all rinse stations.

The costs for Options 1 and 5 show a comparison of CTF and in-plant processing (Table 12). For this particular shop, the option of sending its waste to a CTF as opposed to in-plant treatment would save $43,900 annually.

For large metal finishing facilities (greater than 75,000 gpd), the most common selection of treatment alternatives was Option 4 (treating all waste streams in-house and sending dilute sludge to CTF for dewatering). An example of the results for a typical large facility are presented.

Shop E6 works with automotive parts, appliances, and industrial parts, such as fasteners and stampings. Aside from electroplating, process water uses include pickling, cleaning, surface neutralizing, chromating, phosphating, bright dipping and chemical polishing, and stripping. The current process wastewater discharge for E6 is 225,000 gpd. The shop operates 24 hours per day and 340 days per year. The shop is located 8.5 miles from the CTF site.

E6 has 35 rinse stations, all of which have flow control valves and approximately half of which have counter-current rinsing. Rinse stations without counter-current rinsing have no potential for installing counter current.

This shop currently has no pretreatment. The effluent analysis (Table 13) indicates a need for chrome reduction (assuming hexavalent chrome exists), cyanide oxidation, and heavy metal precipitation.

The computer results show that the use of a CTF for all waste streams (Option 1) would be the most expensive alternative (Table 14). The least cost alternative is Option

Table 12
Costs for Shop Fl Considering Options 1 and 5
(All Costs in 1980 Dollars Per Year)

	Investment	*Operating Costs*	*Chemical Costs*	*Total In-Plant Costs*	*Transport Costs*	*CTF Fees*	*Total Costs*
W/o CWT (5)	41,200	17,300	2,600	61,100	0	0	61,100
With CWT (1)*	0	0	0	0	14,000	3,200	17,200
Savings	41,200	17,300	2,600	61,100	-$14,000	-3,200	43,900

*Annualized storage and countercurrent investment costs have been included in transportation costs.

4. With this alternative, E6 would be reducing its original waste stream flow (225,000 gpd) by treating in-house and by sending only a dilute sludge to the CTF for dewatering.

Table 13
Analysis of Final Effluent - Shop E6

Flow	225,000 gpd
Chrome (total)	8.5 mg/l
Zinc	21.8 mg/l
Cadmium	53.7 mg/l
Iron	15.8 mg/l
Cyanide	15.5 mg/l

Cleveland Analysis with Multiple CTF Sites

A two-site CWT case study was performed to investigate the economic effects of simultaneously reducing the costs of transportation and the benefits of economies of scale.

The study used the CTF site (CTF Site 1) of the original analysis and a second site (CTF Site 2), which is located 4.2 miles southeast of Site 1. Metal finishing shops were given the same five options as were available in the original analysis, where each shop could use the facility closest to its location or treat on-site — 47 shops were closest to CTF Site 1, and 56 shops were closest to CTF Site 2. Because of the use of two central treatment facility sites, the average distance of a shop to a CTF was reduced from 7.8 miles in the original analysis to 6.5 miles.

The most economical regional waste treatment scheme (combining CTF Sites 1 and 2) is shown in Table 15. The annual costs associated with this configuration are presented in Table 16. The CWT system configuration changed very little from the original single-site analysis. The major change which occurred concerned four large shops which originally selected Option 4 (sludge only to CTF) now chose to send some or all of their raw wastewaters to the central facility. As expected, the distance to the CTF was reduced for each of these four shops (Table 17).

Table 14
Costs for Shop E6 Considering Options 1, 4, and 5
(All Costs in 1980 Dollars)

	Investment	*Operating Costs*	*Chemical Costs*	*Total In-Plant Costs*	*Transport Costs*	*CTF Fees*	*Total Costs*
Option 1*	0	0	0	0	330,359	60,890	391,250
Option 4	48,000	25,400	50,400	123,800	3,500	1,800	129,100
Option 5	57,400	27,900	50,400	135,700	0	0	135,700
Savings (4 vs. 5)	9,400	2,500	0	11,900	-3,500	-1,800	6,600

*Annualized storage and countercurrent investment costs have been included in transportation costs.

Table 15
Most Economical Waste Treatment Scheme for Cleveland Region Using Two CTF Sites

	Number of Shops	
Option	*Original Case*	*2-Site Case*
1 - All waste to CTF	86	88
2 - Chrome waste and all sludge to CTF	1	1
3 - Cyanide waste and all sludge to CTF	0	2
4 - Sludge only to CTF	15	11
5 - Nothing to CTF	1	1

Table 16
Regional Summary - Cleveland Using Two CTF Sites
(Annual Costs in Thousands of 1980 Dollars)

	Total Plant Investment	*Total Plant Operating Costs*	*Total Plant Chemical Costs*	*Total Plant Costs*	*Total Transport Costs*	*Total CTF Fees*	*Total Regional Costs*
W/o CTF	1,926	1,744	527	4,197	0	0	4,197
With CTF	298	246	199	743	1,118	525	2,386
Savings	1,628	1,498	328	3,454	-1,118	-525	1,811

Table 17
Option 4 Shops Affected in Two-Site Analysis

	1-Site Analysis		*2-Site Analysis*	
Shop Code	*Miles to CTF*	*Option Selected*	*Miles to CTF*	*Option Selected*
P4	4.3	4	2.4	3
N8	4.0	4	0.7	1
E5	3.9	4	2.9	1
E6	8.5	4	4.4	3

The total annual savings for the Cleveland Region under the two-site analysis increased slightly ($48,000) from the original analysis. This indicates that the loss of some economies of scale were less than the savings in reduced transportation costs.

Milwaukee Analysis

Data were collected for approximately 60 metal finishing shops in the Milwaukee metropolitan area. The data shows that 41 of these shops were not meeting 1982 pretreatment standards and, thus, were included in the CWT analysis.

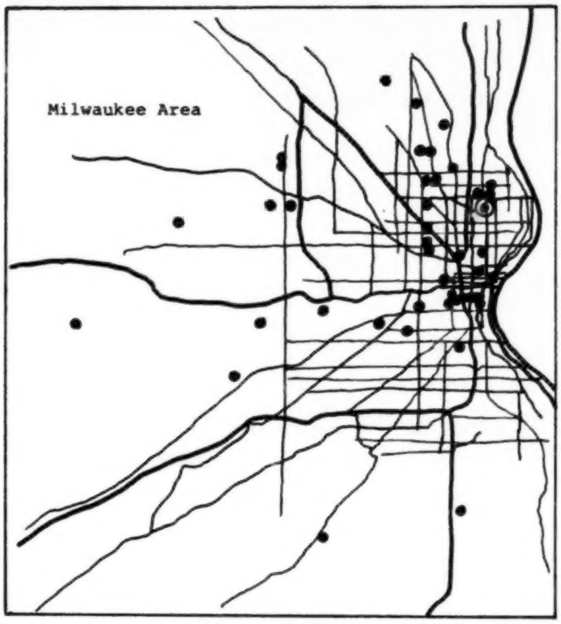

Fig. 5—Metal Finishing Shops in the Milwaukee Area

Table 18
Most Economical Waste Treatment Scheme
For Milwaukee Region

Option	*Number of Shops*
1 - All waste to CTF	23
2 - Chrome waste and all sludge to CTF	3
3 - Cyanide waste and all sludge to CTF	2
4 - Sludge only to CTF	13
5 - Nothing to CTF	0

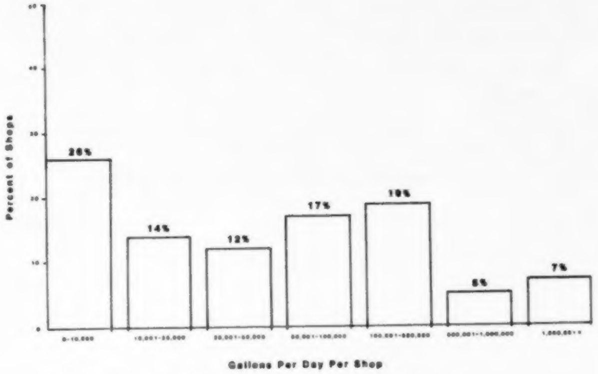

Fig. 6—Distribution of Milwaukee Water Use Flow Rates.

Figure 5 shows the location of the 41 metal finising shops. Most of the shops are located in a 4-mile wide vertical strip along the eastern shore of Lake Michigan. The potential CTF site is located at approximately the center of this eastern strip. The other metal finishing shops are dispersed over a 100-square-mile area. The mean distance between all shops and the potential CTF site is 7.8 miles. The nearest and farthest shops are located 0.1 and 30.2 miles, respectively, from the CTF site. The distribution of water use flow rates for the 41 shops is shown in Figure 6.

The most economical waste treatment scheme is shown in Table 18. The annual costs associated with this configuration are presented in Table 19.

The results from the Milwaukee analysis show the effect of having a high percentage of medium and large shops. For Milwaukee, only 40 percent of the shops use 25,000 GPD or less of water, and 48 percent use greater than 50,000 GPD. In Cleveland, the percentage was 60 percent for less than 25,000 GPD and 27 percent for greater than 50,000 GPD. The effect is that 32 percent of the Milwaukee shops have selected Option 4 (send only sludge to CTF) as the most economical waste treatment alternative; whereas in Cleveland, only 14 percent selected that option.

Philadelphia Analysis

Data were collected for approximately 90 metal finishing shops in the Philadelphia metropolitan area. Fifty-one of these shops were not meeting 1982 pretreatment standards and were used in the CWT analysis.

Table 19
Regional Summary - Milwaukee
(Annual Costs in Thousands of 1980 Dollars)

	Total Plant Investment	*Total Plant Operating Costs*	*Total Plant Chemical Costs*	*Total Plant Costs*	*Total Transport Costs*	*Total CTF Fees*	*Total Regional Costs*
w/o CTF	898	710	249	1,857	0	0	1,857
With CTF	432*	323	220	975	342	120	1,437
Savings	466	387	29	882	-342	-120	420

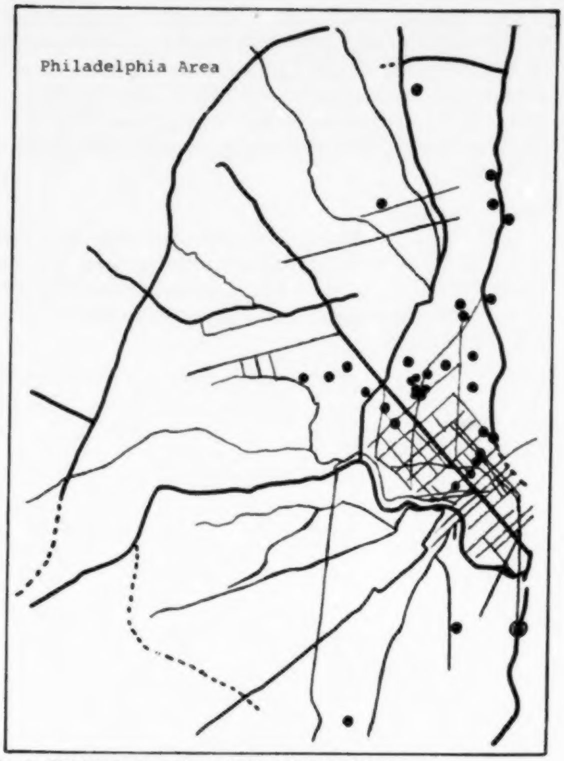

Fig. 7—Metal Finishing Shops in the Philadelphia Area.

Figure 7 shows the location of the 51 metal finishing shops. A major portion of this metal finishing population is located in southeastern Philadelphia, in an area bordered by the Schuylkill and Delaware Rivers. The potential CTF site is located in the extreme southeastern corner of Philadelphia near the Philadelphia International Airport. The mean distance between the shops used in the analysis and the potential CTF site is 10.1 miles. The nearest potential customer is located 2.4 miles from the central site, and the farthest company is located 26.7 miles from the site. The distribution of water usage rates for the 51 shops used in the analysis is shown in Figure 8. The most economical waste treatment scheme is shown in Table 20. The annual costs associated with this configuration are presented in Table 21.

The results of the Philadelphia analysis show a strong resemblance to the Milwaukee results. A large percentage (39 percent) of the Philadelphia shops selected Option 4. Again, this is primarily a result of having a relatively high percentage of medium and large water users (51 percent of shops in Philadelphia use more than 50,000 gpd).

Philadelphia also showed a relatively high percentage of shops selecting Options 2 and 3 (18 percent as compared to 1 percent for Cleveland and 12 percent for Milwaukee). This is primarily a result of having a relatively larger mean distance from the shops to the CTF site. The average CTF distance of the nine Philadelphia shops selecting Options 2 or 3 was 10.0 miles. This caused some waste streams (usually acid/alkali) to be cost effectively treated in-house and for other streams (usually chrome) to be hauled and treated at the CTF.

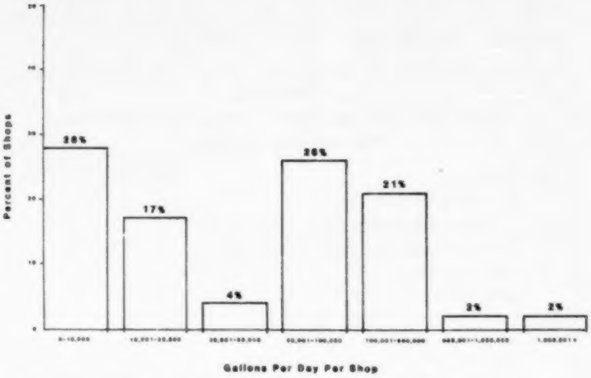

Fig. 8—Distribution of Philadelphia Waster Use Flow Rates

Atlanta Analysis

Data were collected for 54 metal finishing shops in the Atlanta metropolitan area. The available information indicated that 23 of these shops were not meeting 1982 pretreatment standards and were, thus, considered in the CWT analysis.

Most of the 23 metal finishing shops used in the analysis are well distributed in a 20-square-mile area which is centered over downtown Atlanta (Figure 9). The potential central facility site is located 5 miles southeast of the center of the city. The mean distance between the shops and the potential CTF site is 5.6 miles. The nearest and farthest shops are located 2.2 and 11.6 miles, respectively, from the potential CTF site. The distribution of water use flow rates is shown in Figure 10.

The most economical waste treatment scheme

Table 20
Most Economical Waste Treatment Scheme
for Philadelphia Region

Option	*Number of Shops*
1 - All waste to CTF	22
2 - Chrome waste and all sludge to CTF	8
3 - Cyanide waste and all sludge to CTF	1
4 - Sludge only to CTF	20
5 - Nothing to CTF	0

Table 21
Regional Summary - Philadelphia
(Annual Costs in Thousands of 1980 Dollars)

	Total Plant Investment	*Total Plant Operating Costs*	*Total Plant Chemical Costs*	*Total Plant Costs*	*Total Transport Costs*	*Total CTF Fees*	*Total Regional Costs*
W/o CTF	1,189	961	1,020	3,170	0	0	3,170
With CTF	661	560	995	2,216	478	84	2,778
Savings	528	401	25	954	-478	-84	392

considering in-plant treatment and CWT is shown in Table 22. The annual costs associated with this configuration are presented in Table 23.

Table 22
Most Economical Waste Treatment Scheme for Atlanta Region

Option	*Number of Shops*
1 - All waste to CTF	19
2 - Chrome waste and all sludge to CTF	0
3 - Cyanide waste and all sludge to CTF	0
4 - Sludge only to CTF	4
5 - Nothing to CTF	0

The Atlanta results show a relatively good CWT system participation. This high CWT is primarily a result of the closeness of the shops to the central treatment facility site (mean distance 5.6 miles). The four Option 4 shops in the analysis are large shops (greater than 50,000 gpd) most of which are located 10 or more miles from the CTF site.

Seattle Analysis

Data were collected for approximately 60 metal finishing shops in the Seattle metropolitan area. The data showed that 22 of these shops were not meeting 1982 pretreatment standards and were thus, included in the CWT analysis.

Table 23
Regional Summary - Atlanta
(Annual Costs in Thousands of 1980 Dollars)

	Total Plant Investment	*Total Plant Operating Costs*	*Total Plant Chemical Costs*	*Total Plant Costs*	*Total Transport Costs*	*Total CTF Fees*	*Total Regional Costs*
W/o CTF	404	341	81	826	0	0	826
With CTF	80	61	51	192	217	92	501
Savings	324	280	30	634	-217	-92	325

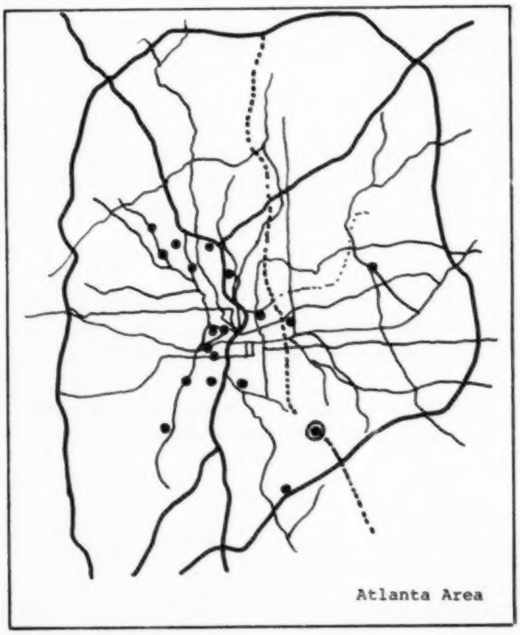

Fig. 9—Metal Finishing Shops in the Atlanta Area.

Table 24
Most Economical Waste Treatment Scheme for Seattle Region

Option	*Number of Shops*
1 - All waste to CTF	11
2 - Chrome waste and all sludge to CTF	0
3 - Cyanide waste and all sludge to CTF	0
4 - Sludge only to CTF	11
5 - Nothing to CTF	0

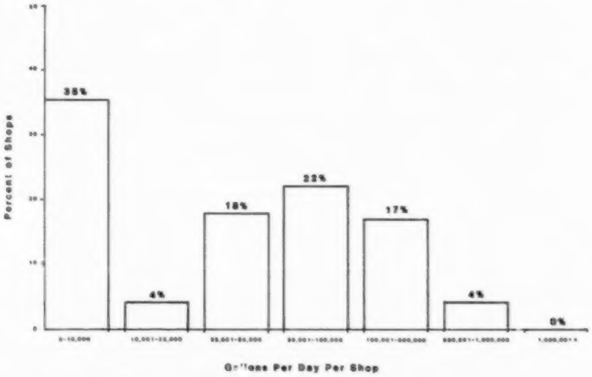

Fig. 10—Distribution of Atlanta Water Use Flow Rates

Figure 11 shows the location of the 22 metal finishing shops of concern. The majority of the shops are located between Puget Sound and Lake Washington. The remainder of the shops are located in the northern portion of King County and in the Kent area. The potential CTF site is located near the southern two shops in Kent. The mean distance between the shops and the potential CTF site is 16.6 miles. The nearest and farthest shops are located 2.1 and 33.2 miles, respectively, from the CTF. The distribution of water use flow rates is shown in Figure 12.

The most economical waste treatment scheme is shown in Table 24. The annual costs associated with this configuration are presented in Table 25.

For Seattle, the greatest factor was the hauling distance. Although 76 percent of the metal finsihing population considered in the analysis used less than 50,00 gpd of water, only half of the total number of shops sent raw waste streams to the CTF. The mean distance to the CTF for the plants selecting Option 4 was 19.5 miles. For the remainder of the shops, the mean CTF distance was 12.8 miles.

Table 25
Regional Summary - Seattle
(Annual Costs in Thousands of 1980 Dollars)

	Total Plant Investment	*Total Plant Operating Costs*	*Total Plant Chemical Costs*	*Total Plant Costs*	*Total Transport Costs*	*Total CTF Fees*	*Total Regional Costs*
W/o CTF	367	319	22	708	0	0	708
With CTF	156	133	17	306	154	65	525
Savings	211	186	5	402	-154	-65	183

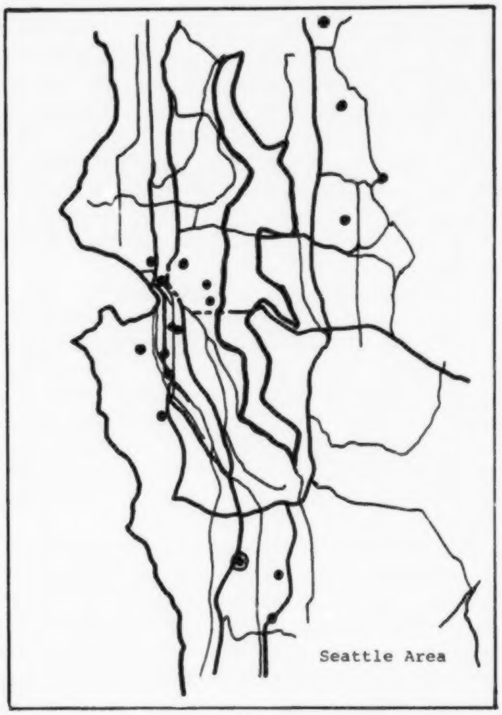

Fig. 11—Metal Finishing Shops in the Seattle Area.

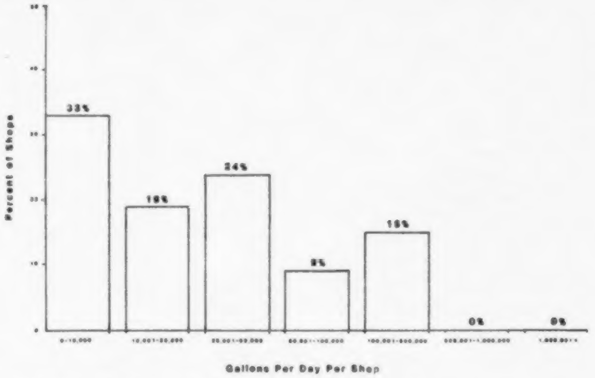

Fig. 12—Distribution of Seattle Water Use Flow Rates.

PHASE II CWT SYSTEM DESIGN

Phase I of this project investigated the feasibility of CWT and defined the conditions necessary for its successful implementation. The second phase is directed at developing and demonstrating procedures for creating CWT systems. This is being achieved by selecting one area for detailed study to develop a comprehensive metal finishing waste control plan for that area. The process for selecting the Phase II area and an overview of the subsequent study and analysis are presented in the following paragraphs.

Selection of Phase II Study Area

The Phase II area was chosen as the most feasible site for central waste treatment from a technical, economical, political, and administrative standpoint. The selection procedure utilized by the project team to identify the most feasible area had two basic steps:

- Screening Exercise
- Assessment of Economic Feasibility

The objective of the screening exercise was to provide a quantitative and rational means of selecting from the 24 metropolitan areas studied in Phase I, the most likely candidate areas for the Phase II centralized waste treatment study. The procedure that was utilized was similar to the selection process used in Phase I to choose the five case study areas, the basic decision tool being the worth assessment model.

The criteria used in the Phase I worth assessment exercise were expanded to satisfy additional requirements of Phase II. First, an area to be selected should have available from local authorities water use and industrial discharge data that characterizes its metal finishing population. This information would be needed for the subsequent modeling to determine economic feasibility. Secondly, it was determined that it would be advantageous from a project administrative standpoint if the municipal contact for the project was in a high visibility position with broad authority. In some cities, the contact's authority was limited to the municipal wastewater system. In these cases, it was difficult to obtain information on solid waste disposal sites and on other data requirements related to economics or land availability.

In other cities, contacts included environmental directors that had an overview of both wastewater and solid waste control, economic development administrators that were aware of the availability of land for potential CTF sites, or personnel from the mayors' offices that had a comprehensive view of all information needed during this project. These various levels of contacts were weighed as to their ability to supply the appropriate project information and generally contribute

Table 26
Results from Sensitivity Analysis - Case 2

Location	*Value*
Cleveland	0.78
Seattle	0.71
Philadelphia	0.68
Tulsa	0.66
Atlanta	0.63
Buffalo	0.6
Erie	0.6
Chicago	0.56
Trenton	0.51
Dallas/Ft. Worth	0.46
San Francisco	0.4
Boston	0.37
Alburquerque	1
Canton	0
Cincinnati	0
Denver	0
Houston	0
Miami	0
Milwaukee	0
Rochester	0
San Jose	0

to the project. After inclusion of the additional criteria, the worth assessment model was utilized.

The results from the exercise are shown in Table 26. From these results, it is evident that the metropolitan areas of Seattle and Cleveland best satisfy the Phase II criteria. These metropolitan areas were considered in the second step of the Phase II selection procedure.

Assessment of Economic Feasibility

To perform the economic assessment, a simplified version of the Phase I analytical model was developed and applied to metropolitan areas with the highest worth assessment scores.[1] The project plan first was to determine the economic feasibility of CWT in Seattle and Cleveland. Then, if neither area appeared promising, other cities, starting with Philadelphia, would be added to the analysis.

From the modeling exercise, it was concluded that the Cleveland metropolitan area presented more favorable economic conditions for CWT implementation; therefore, Cleveland was selected as the study area for the Phase II portion of the project.

DATA COLLECTION AND ANALYSIS

The Phase II analysis was to be more in-depth and comprehensive than the case studies of Phase I. A new and more sophisticated tool was developed for providing additional treatment options, such as in-plant waste stream concentration using ion exchange.

The data requirements of Phase II demanded that the information base collected via the industry survey be expanded. This was accomplished through on-site engineering surveys at the major metal finishing shops in the study area. Surveys of 66 companies were conducted during a 6-week period in early 1980 for data collection purposes.

The on-site surveys consisted of discussions with plant personnel, a tour of the plating facility, and waste stream sampling. For each shop, a schematic diagram of the plating lines was drawn to illustrate the sequence of manufacturing processes showing rinse water flow rates and indicating which baths were batch dumped and the frequency of their discharge. Also, for each rinse tank, it was noted if flow reduction measures such as still or counter-current rinsing, flow control valves, spray rinsing or recovery technology, were in place, or could be added.

Sampling of the final discharge was performed at shops for which municipal data did not exist. Also, individual samples, such as rinses following cyanide or chrome-containing baths, were taken from particular waste streams to establish parameters that would be used in the analysis.

The new analytical tool that was developed for the Phase II analysis was an optimization model. The model is a mixed-integer, linear-program algorithm that has a function similar to the micro computer model used for the case study analysis. The new model, like its simplified predecessor, determines the least cost regional waste treatment scheme considering in-plant treatment and CWT for typical wastes generated by metal finishing companies.

The optimization model contained several important advantages over the micromodel. First, included in the new model was an additional in-plant technology, ion-exchange. Shops were given the option of using ion exchange units with applicable plating baths. It was assumed the units would be installed on still rinses following plating tanks and used to concentrate the waste stream for shipment to a central treatment facility. Concentrating techniques are available for other plating methods.

Another advantage of the optimization model is its ability to consider the choice of multiple CWT sites (the micromodel was limited to one potential CTF site per analysis). This option should be considered when a regional area is planning CWT so that volume reductions can be facilitated. Several central waste treatment plants may significantly reduce transportation costs. Each treatment facility could contain treatment for all waste streams and provide sludge dewatering, or certain facilities could specialize by treating only certain waste streams or be limited to wastewater treatment and transport dilute sludges to another facility for dewatering. The model simulates the most economical combination of treatment sites considering all possible permutations.

The utilization of the Phase II model began last month. The analysis is not yet complete, but preliminary results show a close similarity to the Phase I results.

A report describing the Phase II analysis and presenting results of the study will be completed in June 1980. Also, a 1-day seminar will be held in Cleveland to discuss the results with the local plating industry representatives who have participated in the Phase II study.

MANAGEMENT AND FINANCING OPTIONS

Introduction

Much of the evaluation process for choosing a particular approach must be subjective and is dependent on an assessment of local requirements. Ideally, an objective evaluation of these options should be undertaken by industrial representatives and cognizant officials including state or local economic development officials, municipal sewer agency officials and representatives from the local banking or investment community. Suitable relations with the media and local environmentalists will aid in providing an open dialogue on the purpose of the facility, its backers, and future siting attempts. The following sections provide information on the general approaches to these.

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[1] Phase II of the CWT project was started several months before all the data and results of Phase I were available. This overlapping of project phases was done in response to the urgency to demonstrate CWT before metal finishing companies were committed to in-house treatment for meeting pretreatment standards; therefore, a simplified model was developed to determine relative feasibility.

MANAGEMENT OWNERSHIP OPTIONS

Overview—Management and ownership options fall into three basic categories: private, public, or cooperative ownership. Private ownership would be by firms that specialize in waste treatment and disposal, although it is possible that a single electroplater could build a CTF to handle his and other platers' waste. Public ownership could be by state, county, municipal, or quasigovernmental economic development corporation. Finally, cooperative ownership implies either a joint venture or a general-limited partnership of CTF users.

In addition to full private and full governmental electroplater cooperative ownership, there are two scenarios that represent variants to the basic management options. These include:

- Government or electroplater ownership of the land with an outside firm owning and operating the CTF
- Governmental or industry ownership of the land, buildings, and equipment used in the CTF with an outside firm being hired to manage the facility

Table 27
Possible Management Ownership Options*

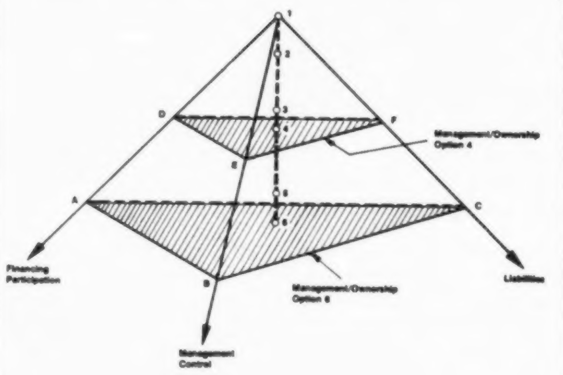
Complete Private Ownership	1. Complete ownership, financing and management responsibility by an outside firm.
	2. Complete ownership, and management responsibility by an outside firm with financing assistance (i.e., loan guarantees, loans, or non-recourse financial investments) by state/local government and/or an industry user group.
	3. Ownership, financing and management responsibility by an outside firm of a CTF built on government-owned or industry-owned land.
	4. Ownership and management responsibility by an outside firm of a CTF built on government-owned or industry-owned land state/local government and/or industry financing assistance.
	5. State/local government and/or industry user group ownership and financing of a CTF which is managed under contract by an outside firm.
Government and/or Industry User Group Ownership	6. Complete state/local government and/or industry user group ownership, financing and management responsibility.

In Table 27, these three options are distributed into six management scenarios. While these scenarios are not the universe of all possible choices, they are presented as a representative cross-section and should be modified for local conditions.

The selection process will be influenced in large part by the following factors:

- The level of management control desired by government and/or industry user groups
- The willingness and capability of government and/or industry user groups to participate in financing
- The level of liability for CTF operations that government and/or industry user groups are willing to accept

Management control over the pricing of services and the user access to a CTF will, of necessity, be determined by the risk associated with the potential dangers of handling and disposing of hazardous materials. As shown in Figure 13, if the potential customers and/or local government are concerned that the CTF should service small business and provide the treatment services at a below market user fee, then the potential customers and/or local governmen. will need to be willing to assume a role in the financing package and assume the degrees of risk associated with this participation. If the potential customers want to transfer all of the risks, financing considerations and management problems to a third party, they also must delegrate management control and pricing authority.



Management/Ownership Options:

1. **Complete ownership by outside private firm.**
2. **Complete ownership/management by outside firm with financing assistance by state/local government and/or industry user group.**
3. **Ownership.management of CTF by outside firm. Land owned by government or industry user group.**
4. **Combination of Options 2 and 3.**
5. **Ownership by state/local government and/or industry user group. Contract management by outside firm.**
6. **Ownership/management by state/local government and/or industry user group.**

Fig. 13—Financing Participation, Control, Liabilities and Management/Ownership Options.

Private Ownership

Private ownership delegates complete management control of operating liabilities and financing responsibilities to a private firm providing a service similar to chemical suppliers. While it prevents local government and industry from exercising extensive control over customer selection or user fees, it requires no capital outlay for facilties by electroplaters. The responsibility of compliance with appropriate wastewater treatment and solid waste regulations is delegated to a responsible private concern.

Private Ownership Using Public Financing Assistance

The economics of scale are the primary attraction of centralized waste treatment facilities, though market competition by competing private centralized treatment facilities will ensure that small business customers are likewise serviced and that reasonable user fees are charged. Many potential treatment firms are limited by their access to investment capital; therefore, local government can assist in providing traditional financing assistance through loan guarantees, direct loans, or equity investments.

Private Ownership Using Government Land—Attracting private capital into this treatment business can be assisted by providing suitable government owned land at reduced or token lease prices. Since these treatment facilities must be in industrialized areas near the plating community, higher land cost may raise the user fees for potential users. However, if the local government provides suitable land at a reduced price, the attraction to private firms will increase.

Private Ownership in Management with Public Financial Assistance in Land Aquisition. A hybrid of the two previous sections combining financial assistance and land dedication could provide the maximum incentive for private concerns to enter the business and provide local participation in managerial control. For example, if a consortium of industry users purchased and dedicated a track of land or contributed capital to the facility, it would be in a position to negotiate for long-term contracts and certain liability surety.

Government or Cooperative Ownership with Contact Management] The Federal Government owns several nuclear reactors that are operated on a contract basis by private firms. Similarly, a centralized facility owned by an industry cooperative and operated by contract management can be conceived. Cooperatives similar to those used for gain and other farm commodities could be capitalized by the electroplating industry and managed by a contractor.

Government or Electroplater Cooperative Ownership. This approach is similar to the one described previously except that control over the design, construction, and operational management of a centralized facility is maintained by the government or industry consortium. Management by some form of Board of Trustees or general partner (as in a limited partnership) would place operational responsibility with the partner.

Financing Options

Overview. The options available to capitalize central facilities are numerous and include traditional private source bank loans or corporate bond issues as well as Federal and state programs designed to assist businesses. Hybrids and combination of these financing approaches can be considered and tailored to available programs and local needs. The success of a potential package will require resourcefulness and creativity in developing and financing plans responsive to individual situations.

Conventional Loans. Conventional loans are available from lending institutions to finance projects of this type, assuming existing corporate financial strength is supported by well established ties with the financial community. The current credit markets dictate loan availability and credit rate.

Debentures. Private investment funds raised by issuing debentures are direct obligations of the issuing corporation dependent entirely upon its general credit rating, reputation, and prestige. These are normally used by large, financially successful companies as a means of raising capital through debt financing. Minimum dollar requirements are required to justify the underwriting costs.

Small Business Investment Corporations. The Small Business Investment Act of 1958 authorized the creation of Small Business Investment Corporations (SBIC) to provide long-term capital to small businesses. Approval by the SBA, which licenses SBICs, is required if the SBIC wishes to invest more than 20 percent or $500,000 in a single small business concern. SBICs may be unable to solely underwrite a capitalization of this type; however, they may play a role in developing an overall financing package.

Industrial Development Bonds. Tax exempt industrial development bonds can be issued by state or local government for financing industrial development. IDBs issued for pollution control financing do not have a dollar limitation; however, using this mechanism to promote industrial pollution projects with tax exempt status requires strict adherence to state and IRS regulations. Until recently, few small firms were able to utilize this source of capital because investment bankers required minimal credit risks and guaranteed repayment for financing this debt on nonproductive pollution control facilities.

Small Business Administration Guarantees. In 1976, Congress authorized SBA to guarantee 100 percent of a small business's obligation to finance a pollution control facility. PL-94-305 assures that smaller firms can obtain favorable financing rates and terms similar to those of major corporations. Guarantees of this type are to be used by credit worthy businesses and no credit denial by a bank is required. Section 8 of the Federal Water Pollution Control Act and PL-94-305 provide the following programs to small businesses:

- SBA Pollution Control Revenue Bond Guarantees
- SBA Loan Guarantee
- SBA Participation Loan
- SBA Direct Loan
- SBA Section 502 Programs

Bond guarantees are made to small viable credit worthy companies to provide low-interest, long-term financing for pollution control needs. Firms must have been in business for at least 5 years and profitable for at least 3 of those 5 years.

Loan guarantees are provided for those businesses unable to obtain conventional bank loans and would otherwise suffer substantial economic injury to comply with Federal treatment regulations. Some financial positions and reasonable repayment assurance are required, but provides advantageous interest rates.

SBA also may participate in a loan with a bank. Normally, SBA's maximum participation is 75 percent of the project cost; however, if a bank exceeds its lending limit, SBA share may be raised an additional 15 percent. Direct loans up to $500,000 are available for acquiring pollution control equipment.

SBA can assist local development companies in creating facilities for small businesses. Section 502 of the Small Business Investment Act of 1958 allows for loans for facilities that small businesses may lease or purchase.

Economic Development Administration. The Federal Government takes a major role in restoring economically depressed areas through the Public Works and Economic Development Act of 1965. Eligible programs in specially designated areas are as follows:

- Direct grant for government owned projects
- Supplementary grants to augment other grants when applicants are unable to meet local government shares
- Loans in severely distressed areas for financing public works; 65 percent for industrial and commercial expansion; 90 percent for working capital and fixed assessed loans.

Other Federal Programs. The Farmers Home Administration and the Department of Housing and Urban Development may be further sources of information on Federal programs subsidizing projects that are in the public interest. Municipal bonds and state programs should be likewise investigated when considering a financing approach.

Summary. Financing and management of a central facility may provide for its success or failure. Strong considerations should be given to the specific requirements of the user community, Federal, state, and local governments, and the financing community. The major requirement falls, however, upon the potential user community in providing a united front towards creation of these facilities. Participation by the industry developing this treatment capacity will help assure its success.

Hazardous Waste Management Facilities: The Siting Problem and Possible Solutions

Frank Boni*

INTRODUCTION

Waste disposal from the surface finishing industry was cited as one of the most serious problem areas in both of the two previous AES/EPA Conferences. A year ago in this meeting EPA's John Lehman (1) estimated that 90% of all waste disposal facilities will not be environmentally acceptable. That is, they will not meet the prospective RCRA requirements.

The problem regarding surface finishing wastes is simply this: Landfill capacity is limited and surface finishers may be unable to find safe, legal disposal facilities. And public opposition to siting may delay the development of additional disposal capacity.

The problem is widely attributed to more stringent environmental standards coupled with public apprehension regarding waste management facilities, particularly facilities sited or proposed for siting in "my backyard."

While it appears there is a role for state governments in the solution of the problem, perhaps there is also a role for the surface finishing industry and the AES, an educational role.

Legislation and Regulations

Waste disposal options have been the target of much legislation. Those disposal options are being increasingly regulated to minimize their potential threat to the public.

As a consequence of the Federal and State activities there are substantial programs in place to enhance air and surface water quality. But the ultimate fate of the pollutants removed from air and water has become a major disposal problem.

Ironically, the earlier statutes actually added to the amount of hazardous waste disposed of on land. For example, the Clean Water Act which affords cleaner navigable waters implies more land disposal for the removed hazardous materials. Concern over this problem led the Congress to pass the Resource Conservation and Recovery Act (RCRA) in 1976. Of particular importance to surface finishers is subtitle C of RCRA which creates a "cradle-to-grave" control system for the management of hazardous wastes.

The proposed RCRA regulations have been reviewed (2) in recent months by the Subcommittee on Oversight and Investigations of the U.S. House of Representatives. That group made recommendations for improving the Act and the regulations. The Subcommittee urged that EPA promulgate those regulations at the earliest possible date, noting that their promulgation is the key to enforcement of RCRA. (Sections 3002, 3003 and 3010 applicable to generators and transporters were being issued as this paper went to press.)

Public Opposition

In a letter (3) to the Electroplating Industry in regard to the problems associated with production, treatment and disposal of wastes, AES discussed the September 7, 1979 electroplating pretreatment standards and forthcoming solid waste regulations. Executive Director Schumacher wrote:

> "These new regulations will require the metal finishing industry to improve its waste water and sludge treatment and disposal practices."

There are several practices available for disposal of sludges. Myron Browning and his associates discussed them in this meeting last year (4). Methods included were landfills, reclamation, chemical fixation and heat treatment. They concluded landfill disposal is still the most common practice in the plating industry and will probably be so as long as the recovery processes are not economical.

However, community acceptance of the establishment and operation of new landfill facilities (and continuing operation of existing facilities) may prove to be the most difficult aspect of the problem associated with those landfills. The Comptroller General in his report to the Congress (5) describes public opposition as the major barrier to expanding disposal capacity:

> "Information obtained from State and industry officials, representatives of environmental interest groups, and environmental impact statements indicate that people are against the permitting of sites for many reasons. For example, people are fearful of groundwater contamination, air and land pollution, fires, explosions, spills, rodent damage, odors, and dust dispersion. They complain that if a hazardous waste facility is built near them, the value of their homes will decline and future real estate development will be inhibited. They protest

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that they do not want their community to be known as a 'dumping ground' for other people's waste."

Public Opposition: Coping With It

Public opposition to the siting or expansion of landfills or even continuation of existing landfills takes different forms. The more visible opposition may be witnessed on the television screen as the news cameraman focuses on an obviously disturbed citizenry carrying placards and blocking entrance to a landfill in the community. A less dramatic, but perhaps more effective opposition, is the power held by many municipalities to control development through zoning or other regulations.

Increasingly it seems that it might be necessary for the state governments to become involved in the siting process if reason rather than emotion is to be determinant. If state involvement is appropriate, the questions that arise include:

- What is the preferred form of involvement by the state government in the siting process?
- How and when should the public participate in the siting process to best assure that facilities are safe?

As for the form of state involvement, our view is that the private sector will provide the necessary disposal facilities if the states create a regulatory framework. An opposite point of view is that private enterprise will not be able to meet the demand for legal disposal when the new standards become effective. Accordingly, such advocates reason that the government should establish disposal facilities with operation either by the State or contracted to private industry. With regard to this controversy, it is worth noting that there is no provision in RCRA for any Federal support for facility construction on the Congressional premise that the private sector would respond if given a regulatory program.

There are already a few models for state involvement in the process of siting of landfills. However, because those models are so new there is very little experience to validate them. The 1979 Michigan "Hazardous Waste Management Act" (6) provides for a site approval board. That board will review and grant or deny final approval for each site construction permit application recommended for approval by the State's environmental agency, the Department of Natural Resources (DNR).

New York's Industrial Hazardous Waste Management Act is proposed to be amended to give facility siting boards the discretion to supersede local zoning in those cases where such zoning is considered unfair, arbitrary or generally not in keeping with the overall public interest (7).

At least one trade group, the National Solid Wastes Management Association (NSWMA), has formally expressed its attitude regarding state involvement in the siting process (8). They suggest the states provide mechanisms for overriding local zoning ordinances when necessary and that incentives be paid to a host municipality by the users of a facility.

The three preceding concepts of state involvement in the siting process include mechanisms for public participation. Public participation in the Michigan siting protocol takes the form of representation on the 9-member site approval board. That board which acts on applications aproved by DNR includes four temporary positions filled by residents of the minicipality and the county in which the disposal facility is proposed to be located. Two of the permanent representatives are also public members, one is to be a geologist and the other a chemical engineer, both of whom are from faculties of Michigan's higher education institutions.

In New York one of the options under consideration includes an independent agency or organization to be created to serve as a mediator and to negotiate agreements between citizens and the proposed developers of a hazardous waste facility. New York would ensure that the resulting agreements were made binding by the incorporation into the permits and certificates which are required before the facility could be constructed and operated.

Mediation, as a negotiated process for resolution of public conflicts, has been successful in some recent controversies (9). The mediation process is getting increasing attention. There is report (10) of a mediation/compensation concept being advocated to the EPA. There are two central ideas in the proposal:

1. The most effective way to deal with the social and political issues is community compensation through mediation, and
2. Siting strategies must be adopted on the state level. EPA's role would be to promote the compensation/mediation strategy among the states.

In their position paper NSWMA also provides a mechanism for social appraisal of a site application that has received favorable environmental review. NSWMA advocates establishment of a siting board whose makeup would be similar to that of Michigan.

Donald Andres recently predicted (11) the solution of this problem (public acceptance of proposed disposal sites) will be an emerging planning partnership between state governments and the waste producing/waste service industry. At this writing we are working hard in Pennsylvania to develop such a partnership by way of an Industrial Advisory Group to the Department of Environmental Resources (DER). The Advisory Group consits largely of industrial waste generating companies. That group appointed a subcommittee from the waste service industry to assist them in the siting recommendations they are creating for the DER. DER will consider those recommendations in the legislation proposals they are developing for the General Assembly. It is too early to appraise the success of this new government/industry partnership.

Education: A Role for AES?

In all the preceding ideas for resolving the social/political issues through public participation the assumption is made that the public has adequate awareness of the need for disposal facilities and is able to distinguish among the risks and benefits posed by the facilities.

Yet such public awareness cannot be taken for granted. An educational effort directed at raising the level of understanding (not to be confused with propaganda) needs to be undertaken. Perhaps EPA through its Office of Public Awareness can provide support for this effort, but it seems the effort is more likely to be successful if implemented at the local level. I feel that local industry has both an obligation and an opportunity in this educational regard.

Local industry is best situated to "know" its community, its attitudes and its awareness. That industry also knows best its own needs for waste management facilities; local industry can best justify its needs in terms of facilities, investment and jobs. Such advocacy by local industry will require a real commitment, one that has not been apparent to date.

In the case of the surface finishing industry and metal finishing in particular, it may be that the relatively small size of many of its constituent member companies precludes much involvement. And this circumstance may suggest there is a role, a public education role, for professional and trade organizations such as AES.

If there is a role for AES, the question arises: What message ought AES and its representatives be advocating?

We suggest the message to the public might contain the following elements:

1. Clarify the connection that exists between standard of living and generation of industrial wastes.
2. Identify the need for industrial "waste baskets." The need for waste management facilities grows in proportion to living standards even though manufacturing processes are being improved to reduce wastes and more wastes are being recycled and exchanged every day.
3. Edify as to the basic spectrum of characteristics that are injurious to public health and the environment, i.e., toxic, radioactive, reactive, corrosive, and ignitable, and differentiate from these the nature of the surface finishing industry wastes, particularly those residuals or wastes produced by the chemical treatment facilities of the industry.
4. Edify as to the various waste disposal facilities to clarify differences among municipal waste facilities for disposal of household refuse and sanitary wastes, hazardous waste facilities for disposal, destruction and storage of chemical wastes and special waste facilities for storage of residuals produced by the chemical treatment facilities of the surface finishing industry.
5. Edify as to the need for segregated landfills, to keep industrial wastes separate from residential and commercial refuse thereby minimizing the likelihood of formation of leachate which would have adverse impact on groundwaters.
6. Edify as to need for state involvement in the siting process on a basis which provides for public participation in the evaluation of social and economic issues. To be emphasized: Local control is not likely to solve problems.

A Caveat: Things May Not Be What They Seem

The current popular view is that public opposition to new disposal facilities is growing and future sites may even have to be located on Federal and State lands. However, there are recent instances of approved applications for sites owned by the private sector. Are such approvals exceptional or might they indicate a trend?

CONCLUSIONS

Regulations and societal pressures are reducing the available disposal options for the surface finishing industry.

There is need for involvement at the state level in the siting aspect of the growing problem facing the surface finishing industry of finding safe, legal locations for disposal of residues from waste treatment.

State involvement is more likely to be successful if siting procedures include public participation in resolution of social and economic issues.

Education of the public is a necessary precondition for productive participation in the siting process.

The surface finishing industry and perhaps its associated institutions such as AES have a role in increasing the public's awareness of the problem and potential solutions.

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Group Treatment—Options and Economics

Erich W. Salomon and Edward H. Comfort*

ABSTRACT

Group treatment is one alternative for firms faced with the problem of compliance with pretreatment regulations whereby they may achieve the benefits of economy of scale. A preliminary study of the concept as applied to the plating firms within Huntington Industrial Park, Providence, R.I., was conducted. It was found that, with the assumed ten participating firms, substantial savings could be realized. The effects of financing cost and wastewater hauling charge on savings achieved were investigated, as were the benefits of installation of a piped wastewater collection system. The most cost-effective decision for each participating firm was identified. An approach to financing the proposed facility is outlined.

INTRODUCTION

The Environmental Protection Agency is currently proposing and promulgating a series of industrial wastewater pretreatment regulations that will reduce the introduction of industrial wastewater pollutant parameters to Publicly Owned Treatment Works (POTWs).

The metal finishing industry, because the nature of its waste discharge is such that it can seriously interfere with the proper operation of POTWs, will be one of the industries most affected by these regulations.[1] Various process wastewater control and treatment technologies will be required, which could have an adverse economic effect, especially for small plants with limited personnel and capital.

At last year's joint EPA/AES Conference on Advanced Pollution Control, EPAs Centralized Treatment Program[2] was described. It was pointed out that the Office of Research and Development at EPA had sponsored research to investigate means of reducing the anticipated economic impact on industry of compliance with pending wastewater and solid waste regulations. Regional centralized treatment was one promising means identified; economy of scale and improved waste management are primary benefits. The results of preliminary studies on the economies of the centralized treatment approach were also presented at last year's conference.[3] It was shown there that the major portion of the economy of scale benefit of the centralized treatment concept could be realized when as few as ten shops decide to participate in the arrangement (Figure 1).

While other papers at this conference report on the present status of research on the regional centralized treatment approach, this presentation is directed at a case study of the private group treatment option. Group treatment, as the term is used here, refers to the joint establishment of a waste treatment facility by a group of shops in close proximity, having similar wastes. Ownership, management, and operation would generally involve the participating companies themselves, although a number of variants are possible. The group treatment facility, while primarily intended for the benefit of its members, could in addition offer to treat the wastes of other small shops having similar waste constituents.

Huntington Industrial Park, Providence, Rhode Island, is a modern industrial park which includes about a dozen firms involved significantly in electroplating. All but one or two of the companies are primarily engaged in the manufacture of jewelry. Ten of the firms have agreed to participate in a preliminary investigation of the technical and economic feasibility of establishing a group treatment facility to treat their wastes. This paper presents the status of that investigation.

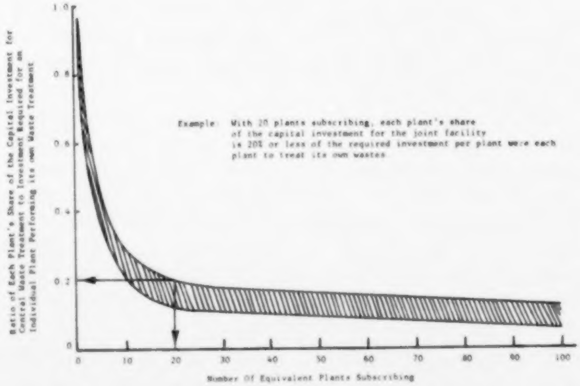

Fig. 1—Effect of Centralized Waste Treatment Systems on Capital Cost Per Plant (from reference 3).

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CENTEC Corporation

BACKGROUND

Pretreatment standards[1] for the electroplating point source category were published on September 7, 1979, with an effective date of October 9, 1979, and a compliance date of October 12, 1982. The regulations identify eight subcategories to which modified effluent limitations apply. Those of primary concerns to the plants in Huntington Industrial Park are the Common Metals Subcategory and the Precious Metals Subcategory. The major difference between these subcategories is the addition of a limitation on the discharge of silver in the case of precious metals. The City of Providence presently intends to enforce standards identical to the Federal requirements. The existence of the 1982 compliance date means that methods of complying with the pretreatment regulations must be considered at an early stage. Thus, EPA's Office of Research and Development has sponsored the present study of group treatment at Huntington Industrial Park at this time as a case study which might be useful as a guide for similar industrial groupings.

The Providence, R.I. region, in which Huntington Industrial Park is located, presents a unique situation with regard to electroplating concentration. No other area in the country has such a high proportion of electroplating firms with respect to the general population. The city presently receives large concentrations of metals in its influent, and calculates that it discharges as much as $30,000 worth of silver each week into Narragansett Bay. The jewelry industry is heavily represented. While it has been estimated[1] that compliance with pretreatment regulations may force about 20 percent of firms in the job shop sector out of business nationally (and other estimates have placed this figure at between 30 and 60 percent)[1], the regional impact of such closures, were they to occur, might be expected to be nowhere of greater significance than in the Providence area. A group treatment facility at Huntington Industrial Park, then, in addition to serving its founding firms, would have the further potential of providing economical waste treatment to those small job shops in close proximity which might otherwise be severely impacted.

Such group treatment facilities are becoming common in parts of Europe and in Japan. Switzerland and the Pforzheim region of Germany have instituted such arrangements. In Japan, with government assistance, electroplaters have relocated to parks where they can easily share waste treatment technology. "In the last several years no fewer than ten industrial parks [one firm to each building] and factory apartments [one building co-owned and occupied by several firms] for electroplaters have been planned and constructed throughout the country."[4]

Chuo Electroplating Industrial Park, built on five acres on an island in Tokyo Bay, is the largest of the parks. Nineteen platers are included (ten of them small job shops forming a united company). The opportunity to relocate and to redesign production lines resulted in modern in-line recycling and recovery systems within each member shop. Combined process water discharge was reduced to a tenth of what it had been—from 300,000 gallons per day to 30,000 gallons per day.

The collective treatment facility at Chuo Industrial Park includes technologies for nickel and copper recovery (by ion exchange and electrolysis), chromic acid recovery from contaminated chromium plating baths (electrodialysis), a regeneration system for spent ion exchange cartridges, and conventional precipitation and dewatering facilities for settling out solids and concentrating sludges. Fixed expenses of the joint treatment facility are shared monthly by all of the members, regardless of the extent to which they have used the facility, on the basis of the area which each member occupies in the park. These expenses include wages and the cost of servicing the debt. On the other batch dumps over a one-month period to find a daily mean. Results of the first method was used to assit in concentration of each type of waste sent to the collective facility by the member.

In the United States, there have been previous studies of the group treatment concept. The Environmental Protection Agency provided a grant in 1977 to study the feasibility of joint treatment of plating wastes in Taunton, Massachusetts.[5] A unique feature of this region, however, was the fact that local pretreatment regulations, more stringent than existing direct discharge limitations, had forced most potential participants to have already committed to a treatment scheme. Thus, only three firms participated in the study. Because the firms were some distance apart, and because only piping of wastewater was considered, it was found uneconomical to jointly treat concentrated rinsewater, but it was found that a joint facility to treat batch dumps in common could provide an operating cost advantage. Certain institutional problems were identified, such as the need to insure that feasibility of the arrangement did not depend significantly on future business decisions of one of the participants. Financing, at the time of the study, was found most likely to depend on the existence of a single company financially strong enough to borrow the necessary funds. The concept was found to have considerable promise, but was not suitable for the particular participants and circumstances existing in Taunton at that time.

At present the Brooklyn Economic Development Corporation is studying the concept of a "Plating City", wherein some of the electroplating industry in Brooklyn, New York, would be consolidated in an industrial park incorporating cogeneration and joint wastewater treatment facilities.[6] The initial study shows considerable potential cost benefit to the participants. While the plating city concept, unlike the present study, involves moving of platers and energy costs reduction through cogeneration, the Brooklyn study did find that a group of ten assumed platers (consisting of eight small and medium shops and two large shops) would reduce both their investment costs and their annual operating costs each by a factor of approximately 2 by joint rather than individual treatment.

Huntington Industrial Park is located within Providence at the Cranston, R. I. boundary. It is well served by highways and nearby access ramps. Although on the outskirts of the city of Providence, it is centrally located with regard to the bulk of the electroplating and jewelry industry in the area.

The park is about ten years old. Although not planned as an electroplating park, there is presently a concentration of plants performing plating. Eleven plants within the park fall into that category. Each of the firms is in the business of jewelry manufacturing with the exception of one plating job shop and one electronics concern. The plants involved range in size from 25 to 350 employees. The average number of working days per year for these firms is 242. All are one-shift operations, and the length of a shift is eight hours in all but two cases.

Several of the firms perform precious metals plating. Gold and silver are generally recovered using in-line processes (electrolysis, ion exchange). Most of the firms make extensive use of cyanide baths. There is very little use of chromium (chromium was found in small quantity in the effluent of only two plants). In addition to cyanide, typical effluents include copper, nickel, and zinc. Some effluents show substantial iron. Little cadmium or lead is in evidence.

Each of the companies presently discharges its industrial waste streams to the City of Providence POTW. Each of the firms may expect to be impacted to some extent by the mandated requirements for pretreatment.

Figure 2 presents a sketch noting the location of the firms performing plating within the park.

A preliminary analysis was performed in order to investigate the technical and economic feasibility of establishing a joint treatment facility within Huntington Industrial Park to treat the wastes of the platers in the park. Transport of the wastes by both piping and truck transport was considered. The next section of this paper discusses the collection of data and the assumptions made for the purpose of performing the analysis.

DATA PREPARATION

The analysis which follows evaluates the benefits of group treatment when compared with the alternative of each plant performing its own treatment. The cost model used computes investment and operating costs of the treatment technologies employed based on flow rates and pollutant concentrations.

In order to determine wastestream flows and pollutant concentrations being discharged by the firms in the park, CENTEC engineers and technicians spent the week of February 15, 1980, at Huntington Industrial Park collecting the needed data. Ten firms indicated sufficient interest in the project to allow a sampling team of three persons to spend, on average, one-half day in each plant.

Wastewater streams were divided into cyanide-bearing and other (general acid/alkali). The flow from the first running rinse following each cyanide bath (expected to carry most of the cyanide to the sewer) was measured and a composite sample of the cyanide stream was prepared, the contribution from each rinse being proportional to the flow rate which had been determined. In addition, samples of the final effluent were obtained. Each of the plants' final effluent, at the point measured, consisted only of process water. At one plant, samples were obtained of four different types of process solutions just prior to scheduled batch dumping. The layout of each plating line was determined and schematic drawings prepared. Information on type, volume, and frequency of each batch dump was obtained. Rinse stations on each plating line were examined to note those at which meaningful flow reduction measures were in place (countercurrent rinse, still-rinse, etc.), and those which were candidates for incorporation of flow-reduction measures. The percent of normal production underway at the time of sampling was noted for each firm.

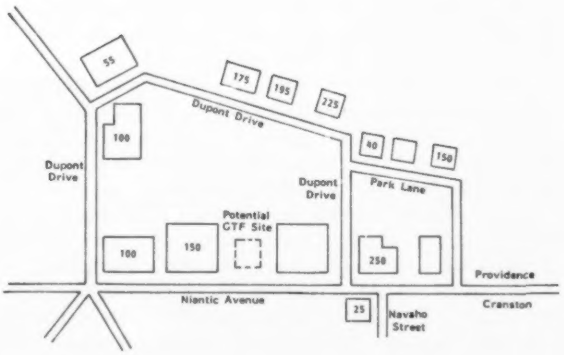

Figure 2.

Samples collected from each plant (except for two which were not in operation at the time of the visit) were submitted to CENTEC Analytical Services, Inc., Salem, Virginia. Analyses were performed for total cyanide, cyanide amenable to chlorination, cadmium, chromium (total and hexavalent), copper, iron, nickel, lead, zinc, and silver. Concentrations measured were corrected to full production based on the assumption that wastewater flows are unchanged regardless of the level of production. The final effluent flow rates, generally not convenient for measurement, were calculated by multiplying the measured cyanide stream flow rate by the ratio of measured total cyanide concentrations, cyanide stream to final effluent. Analyzed concentrations were corrected for batch dumps using actual concentration data for the one plant where batch dump samples were taken; the remaining plants' concentrations were adjusted using average pollutant data for each category of batch dump as supplied by the Manufacturing Jewelers and Silversmiths of America, Inc.[7] Two methods of batch dump adjustment were used. In the first, all dumps with a frequency of once each two weeks or greater were considered to have occurred on the same day. This gave a worst case figure for comparison with the one-day maximum regulations. The second method averaged all batch dumps over a one-month period to find a daily mean. Results of the first method were used to assist in determining which plants might exceed maximum limits. Results of the second method were used to represent the average daily pollutant load requiring treatment.

The two plants which are potential participants, but which were not in operation at the time of sampling, were represented as the average of the other firms for which data was available. Flow rates for the ten plants ranged from 4,000 to 65,000 gallons per day. Every plant except one was found to exceed cyanide limitations on the final effluent. That plant, because its effluent flow is less than 10,000 gallons per day, did not exceed applicable limitations with regard to any pollutant parameter. Nevertheless, it was included in the analysis because, should local regulations ever impose the same limitations for all parameters presently indicated for plants with flows greater than 10,000 gpd, it would be out of compliance for some parameters.

GROUP TREATMENT ANALYSIS

The CENTEC Centralized Treatment microcomputer model was used to analyze the data described above. The analysis is basically a trade-off of the economy-of-scale savings resulting from joint treatment against the added costs resulting from the need to transport the wastes. The model consists of a series of treatment process cost equations, based on U. S. EPA published relations.[8,9] All costs are updated by use of appropriate cost indices. The model selects the most economical decision for each firm from among four allowed alternatives:

(1) Send all wastewater to the group treatment facility (GTF).

(2) Send all cyanide-bearing wastewater to the GTF; treat other flows in-house and send dilute sludge to the GTF.

(3) Treat all flows in-house; send dilute sludge to the GTF.

(4) Perform all treatment processes, including sludge dewatering, at the individual plant.

Treatment processes considered are conventional cyanide oxidation, physical/chemical treatment (neutralization, precipitation, flocculation, clarification and thickening), and dewatering by filter press or vacuum filter. Dewatering to 20 - 30% solids content is considered essential whether performed in-house or at the GTF, since future disposal regulations will not allow dilute sludges to be placed in landfill, and since volume minimization is required to minimize transportation cost.

Plants which decide to ship wastewater to the GTF are required to install sufficient 5,000-gallon tanks to hold separately one day's production of cyanide and non-cyanide wastewater. The savings to each plant resulting from installation of countercurrent rinse at rinse stations not presently so equipped (if there is room) is computed. If such savings are positive, the plant is charged with the cost of such investment and installation, and the appropriate waste stream flows are reduced accordingly.

Transportation to the group treatment facility was assumed initially to be by 5000 gallon tank truck. The alternative of piping all wastes to the GTF was also considered and is discussed in a later section. The cost of shipping 5000 gallons by truck to the GTF was varied from $20.00 to $40.00. (A typical charge for wastewater hauling is $40 per hour.) The interest rate on borrowed funds was varies from 6 percent to 18 percent. Each plant was assumed to require a 20% return on investment before committing capital to in-house treatment technology. That is, a plant is considered to ship its wastes to the GTF unless by constructing in-house treatment facilities it can realize a savings providing a return on invested capital of at least 20%.

Electric utility costs, a component of operating costs, were calculated by using the $.07/kwh rate prevailing in the Providence area. In addition, operating labor, maintenance, and chemical costs are computed for each process. The capital cost of the group treatment facility is computed as the sum of the investment in each treatment process, multiplied by a factor of 1.65 which accounts for ancillary costs of GTF construction.[10] These costs include site work, excavation, shelter, laboratory, electrical installation, controls, piping, etc., in adding to such non-construction cost as A/E fees, legal fees, and contingency.

Such a factor is not applied to the cost of treatment processes installed within an existing plant, since it is assumed that necessary shelter, utilities, etc., already exist.

Table 1
HUNTINGTON INDUSTRIAL PARK
Group Treatment Analysis Parameter Values

FINANCIAL DATA	
Interest Rates & Equipment Life	
Interest Rate	12%
Return on Investment	20%
Equipment Life	15 years
Transportation and Power Costs	
Transportation Cost	$30.00 ($/5000 gal)
Cost of Electrical Power	0.07 ($/KWH)
Cost Indexes	
Ceman Cost Index	198.00
Chemical Plant Cost Index	246.90
Chemical Wholesale Price Index	287.20
GROUP TREATMENT FACILITY	
Identification	
Region Name	Providence
x Location	0.00 (miles)
y Location	0.00 (miles)
Number of Plants	10
Number of Routes	1
Operational Time	
Hours of Operation	16 (hours/day)
Days of Operation	300 (days/year)
Processes Considered Chromium Reduction Cyanide Oxidation Physical/Chemical Treatment Sludge Dewatering Storage Capacity	

Table 1 shows the values of the financial parameters and the group treatment facility constants used in the analysis.

RESULTS OF ANALYSIS

The calculated annual operating results for the region, consisting of the ten participating firms, are summarized in Table 2. The annualized investment costs shown there represent the amortization of the initial capital investment at 12% over 15 years. Table 2 shows that, although the total waste hauling charges in the park for a year come to $124,540 (this total includes amortized in-plant storage costs as well), an overall annual savings of $119,735 is realized when compared to the costs of treatment without the existence of a GTF.

Figures 3 and 4 show the effect which the financing cost and the transportation charge have on the overall savings achieved. (It has been assumed that the same cost of money applies to financing of individual plant treatment construction and to construction of the group treatment facility.) Figure 3 shows that the annual savings increase rapidly as the interest rate increases. This is because the greater the cost of financing, the more significant the economy of scale factor becomes. Of course, the cost of servicing the debt increases as financing charges increase, but the savings make group treatment even more attractive as interest rates rise.

Figure 4 shows the same information plotted as annual savings vs. the transportation charge. As the cost of hauling each 5000 gallons of wastewater from each plant

Table 2
REGIONAL SUMMARY
Huntington Industrial Park

Hauling Cost = $30/5000 gallons   Interest Rate = 12%

	Total Plant Investment (Annualized)	*Total Plant Operating Costs*	*Total Plant Chemical Costs*	*Total Plant Costs*	*Total Transport Costs*	*Total GTF Fees*	*Total Annual Regional Costs*
W/O GTF	$180,639	$183,489	$29,730.4	$393,858	$ 0.00	$ 0.00	$393,858
With GTF	31,704.4	29,147.1	4,303.41	65,154.8	124,540	84,428.8	274,123
Savings	$148,935	$154,342	$25,427.0	$328,704	$-124,540	$84,428.8	$119,735

Table 3
GROUP TREATMENT FACILITY CONFIGURATION
- Process and Fee Structure -

Process	*Required Capacity*	*Annualized Investment*	*Operating Costs*	*Chemical Costs*	*Total Costs*	*Fee Rate*
1-Chromium Reduction	0.0 gal/day	$ 0.0	$ 0.0	0.0	$ 0.0	$ 0.0
2-Cyanide Oxidation	20,535.1 gal/day	5,751.7	5,776.0	26,051.9	37,579.6	0.0080 $/gal
3-Phys/Chem Treat.	27,500.9 gal/day	17,973.9	10,008.9	3,694.3	31,677.1	0.0050 $/gal
4-Sludge Dewatering	84.6 lb/day	6,287.6	2,323.6	0.0	8,611.2	0.4402 $/lb
5-Storage	27,500.9 gal/day	6,560.9	0.0	0.0	6,560.9	0.0010 $/gal

to the GTF doubles from $20 to $40, the savings decrease by an amount between 12 and 20 percent depending on the interest rate. So it is advisable that the GTF subscribers take care to find the most efficient hauling means available.

The capacity of each treatment process at the GTF required to service the needs of the members is shown in Table 3. Since there is virtually no chromium in the wastewater of the participating plants, no provision for hexavalent chromium treatment is made. The total flow to the GTF is found to be little over 25,000 gallons per day. This is substantially less than the total present wastewater flow of 300,000 gallons per day from the ten plants. This is because: (a) the model found that all plants would find it cost-effective to reduce flow by installing counter-current rinses and/or still rinses at rinse stations where that is possible, and (b) two plants, having some of the largest flows, elected (based on the analysis) not to send all of their raw wastewater to the GTF.

Table 3 also shows a summary of all costs associated with operating each treatment process at the GTF, including the amortized investment cost. A fee for use of each process is then established (break-even operation for the GTF is assumed here), so that each participant is charged based on the volume of wastes which he sends to each process.

Table 4 lists each plant by code and shows the option chosen by each plant and the flows to each GTF process from each plant. Plant No. 1 found transportation of the raw wastewater to be so expensive that it determined its most cost-effective solution was to provide in-plant treatment through the clarification step and to send the

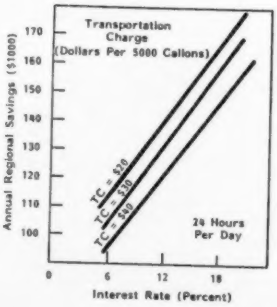

Figure 3.

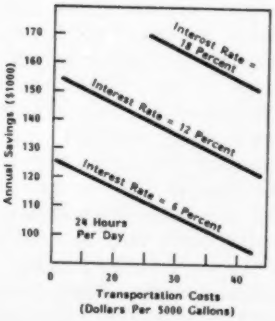

Figure 4.

Table 4
Option Chosen By Each Plant and Flows to Each Process At The Group Treatment Facility

Plant No.	*Option Chosen*	*Average Daily Flows to Group Treatment Facility*		
	-Wastestream to GTF-	*Cn Oxidation Gal*	*Phys/Chem Trtm Gal*	*Sludge Dewatering lb*
1	3- only sludge	0.0	0.0	2.2
2	1- all flow	7797.5	9493.6	21.1
3	1- all flow	549.5	1693.0	10.2
4	1- all flow	639.0	818.5	1.7
5	2- Cn and sludge	646.5	646.5	8.9
6	1- all flow	904.2	2562.0	6.8
7	1- all flow	1476.8	2216.1	0.5
8	1- all flow	970.5	1389.1	4.1
9	1- all flow	1235.0	1553.3	1.6
10	1- all flow	6316.0	7126.7	27.5

Table 5
INVESTMENT REQUIRED WITH AND WITHOUT GROUP TREATMENT

In-Plant Invest. w/o Group Treat.		$1,229,864
In-Plant Invest. with Group Treat.	$215,673	
Capital Cost of the GTF	287,991	503,664
Capital Savings		$726,200

Table 6
GROUP TREATMENT FACILITY CAPITAL COST BREAKDOWN

Cyanide Oxidation	$ 23,059
Phys/Chem Treatment	72,496
Sludge Dewatering	42,772
Storage	36,066
Laboratory, Shelter, etc.	113,598
Total	$287,991

dilute sludge only to the GTF. Certainly that option choice could be changed based on segregation of certain running rinses which do not require treatment and the accomplishment of more flow reduction than the model assumptions allowed. Plant No. 5, with a small cyanide stream flow but a large acid/alkali flow, chose not to treat cyanide in-plant but to sent the cyanide wastes to the GTF. Nevertheless, the large acid/alkali flow was found to be more economically treated in house, sending only the dilute sludge to the GTF. Again, other waste concentration measures could change that solution.

Table 5 shows a comparison of the capital investment in treatment equipment required with and without the group treatment facility. The capital cost of the GTF itself is only 23% of the total in-plant investment required without group treatment. This ratio corresponds closely to the estimate shown in Figure 1 (taken from Reference 3) for 10 subscribing plants. Table 6 shows the capital cost breakdown for the group treatment facility. This is the amount which would have to be financed jointly by the participants. In addition, each plant would have to bear the costs of stream segregation, storage provision, and wastewater flow reduction (included as part of transportation costs in Table 2). The two plants which elected to install some inplant treatment (under this set of assumptions) would have that capital cost in addition.

PIPING OF WASTEWATER TO THE GTF

While truck hauling of wastes was assumed in the previous analysis, the possibility of constructing an industrial wastewater sewer system within the park was considered. A double pipe system, designed to carry cyanide and non-cyanide wastes separately, was evaluated. Two designs were considered: One, a collection system based on gravity flow, the other a pump-assisted system. Figure 5 shows a schematic of the collection system (single pipeline shown) with manholes indicated (17 per line). The basis of the cost estimate is shown in Table 7, and Table 8 presents the breakdown of the estimated cost.

With installation of such a system for collection of wastewater, the total costs of construction are as shown below:

Cost of the GTF Construction	$288,000
Cost of the Sewer Collection System	344,000
	$632,000
Allowance for Additional GTF Flow	150,000
	$782,000

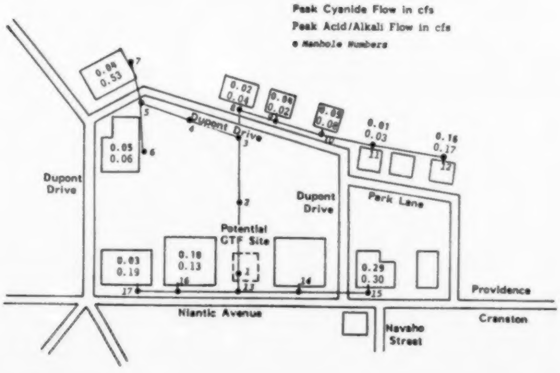

Figure 5.

Table 7
COLLECTION SYSTEM COST ESTIMATE ASSUMPTIONS AND PROCEDURES

Design 1

- Based on peak flows (2.0 times present actual average daily flow) during actual hour of plant operation only.
- Collection system configuration as shown in Figure 5 for single system. Actual system will use same trends for collection pipe wherever possible.
- Design cost estimates.
  - Local (Providence, R.I.) materials and labor costs.
  - Depth to groundwater assumed = 6' (trench will be dewatered using native materials, as necessary).
  - Select backfill used to protect pipe (@ 8CF/LF).
  - Economy for using same trench for 2 systems - 25%.
  - Asphalt replacement necessary for 8 ft. width along 20% of trench length (1.6 SF/LF).

Design 2

- If local codes do not permit use of minimal slopes for small diameter pipes (even though no gross solids are anticipated), it may be necessary to consider a design alternative to the proposed gravity collection system. One alternative would involve installation at each site of a collection sump for each waste stream, a low horsepower pump (¾ hp or less), and controls. The previously designed gravity collection system would simply receive wastes by pumping at a uniform rate when a sufficient waste volume has accumulated at each location, thereby avoiding low flow volumes and velocities. Costs are estimated to be $2,000 per installation for 20 installations, totaling an additional $40,000 (in excess of Design 1 costs).

Choice of this mode of wastewater collection would eliminate most of the annual hauling expense (storage and truck transport) shown in Table 2, although the portion related to in-plant flow reduction would still have to be borne. Amortizing the cost of sewer system installation over the same 15 years at 12% results in an annual charge of $50,568, certainly comparing favorably with the total annual transportation charges shown in Table 2. But it must be emphasized that, even if wastes were to be piped to the GTF, maximum waste concentration through flow reduction would still be required in order to keep the GTF treatment process costs close to the estimate shown.

FINANCING AND MANAGEMENT ALTERNATIVES

The group treatment concept, as the term has been used here, requires that some or all of the companies with wastes to be treated share in the ownership and/or management arrangement. A group of firms, such as those at Huntington Industrial Park, has several alternatives for financing of the proposed facility. Among these are conventional bank loans, industrial revenue bond financing, and industrial revenue bond financing with special SBA repayment guarantee.

The proposed facility will apparently be eligible for either of two alternative tax treatments.[11] The first alternative involves depreciation of the useful life of the pollution control equipment by any IRS-approved method, coupled with the full 10% investment tax credit. Under the second alternative, rapid amortization of pollution control facilities through Section 169 of the Internal Revenue Code may be chosen. If the facility

Table 8
Cost Estimate
Huntington Industrial Park Wastewater Collection System

Item	*Quantities No. Units*	*Units*	*Engineering Unit Cost*	*Estimate Cost*
Pipe, including excavation placing, jointing, and backfilling:				
6" PVC	8770	LF	25.00	219,250
8" PVC	1650	LF	30.00	49,500
SUBTOTAL				268,750
Economy - use single trench for placement of both pipes where possible; Deduct 25%				-67,190
SUBTOTAL				201,560
Manholes	34	EA	1500.00	51,000
Select Backfill	1540	CY	8.00	12,320
Dewatering	5210	LF	1.50	7,820
Asphalt Replacement	900	SY	2.50	2,250
SUBTOTAL				274,950
A&E @ 10%				27,500
Contingency @ 15%				41,240
TOTAL				$343,690 ~ $344,000

qualifies, the investment cost may be written off over a 60-month period, but only one half of the investment tax credit, applicable to the year of purchase, may be taken. Should an incorporated GTF venture show an operating loss, the ability of any of the participating firms to apply that loss against its own business profits may be severely limited, since only a firm owning at least 80% of the treatment facility could consolidate the financial statements. Such tax implications of group treatment require detailed investigation for each proposed arrangement. The financial summaries included in this paper have omitted income tax considerations.

Conventional bank loan financing of the group treatment facility is a possibility. The individual companies involved in the ownership may each qualify for a portion of the loan. The loan could be made either directly to the firm involved or to a corporation formed by the firms to own and operate the facility. In either case, the bank would look to the assets and credit-worthiness of the individual firms.

If applications for a conventional loan result in a turndown, it is possible to qualify for an SBA "economic injury loan" under the Pollution Control Loan Program. Rates are at below-market interest. Roughly one-quarter of such loans made through last year were to electroplaters.[11]

Perhaps the most attractive financing for such a venture is through the issuance of tax-exempt industrial revenue bonds. Such bonds are issued by a public entity. Were such bonds to be issued to finance the proposed Huntington Industrial Park group treatment facility, the likely issuer would be the Rhode Island Department of Economic Development.

Until recently, such bond issues were possible only for large enterprises in strong financial position, since the investor, must rely on the credit of the firm for repayment. But in June 1976 the SBA received authority to guarantee loans to eligible small businesses for the acquisition of pollution control facilities. This SBA guarantee may be for an amount of up to five million dollars, the full amount of principal and interest, and may run for a term of up to 25 years. The funds raised by the public entity (R.I. Dept. of Economic Development in this case) would be loaned to the participating firms. The repayment of these funds by the firms would then be guaranteed by the Small Business Administration. To qualify for the loan guarantee, each firm participating in the ownership arrangement must meet the definition of a small business (for electroplaters, one definition is a firm with fewer than 250 employees) and must have been in business for at least five years, at least three of them profitable. In addition, the participating companies must be financially able to service the debt. But, when tax exempt bond financing is combined with the SBA guarantee feature, the resulting AAA rating provides small businesses with the most favorable financing rates possible, rates heretofore available only to the largest concerns.

Preliminary discussions with a potential underwriter have been held relative to the financing of the Huntington Industrial Park group treatment facility. In practice, such as underwriter, in conjunction with local bond counsel and the issuer, put together the financing package. While joint treatment facilities for electroplaters have not yet been financed under this program, similar joint treatment ventures have been or are being financed under the program for a group of cheese processors, a group of potato cooperatives, and others. A practical limitation may be the fact that when more than three or four firms are involved in the ownership, the administrative costs of putting together the package may become excessive. Because fees for bond counsel, the SBA guarantee, underwriting costs, etc. must come out of the loan proceeds, the advantages of this approach cannot be realized when the amount to be financed is less than $100,000. Were 1-4 of the firms in Huntington Industrial Park to propose to own and manage the group treatment facility under this SBA guarantee program, the SBA would be interested in assuring that firm contractual arrangements give those firms not participating in ownership a guarantee of future access and fair charges.

Platers interested in investingating the SBA Pollution Control Financing Guarantee Program should contact the SBA, Pollution Control Financing Division, Office of Special Guarantees, 1815 North Lynn Street, Magazine Bldg., Rosslyn, Virginia 22209, (703) 235-2900.

RECOMMENDATIONS FOR HUNTINGTON INDUSTRIAL PARK

The proposed Group Treatment Facility has been shown, based on a preliminary analysis, to be feasible for Huntington Industrial Park and to effect considerable cost savings for the participants when compared to their costs of complying with the pretreatment regulations individually. Installation of an industrial sewer system within the park, while more than doubling the demands for initial capital, would be cost-effective in the long run. While the analysis performed has considered only conventional treatment processes, further study is warranted to investigate the benefits of recovery technology for copper and nickel at the GTF. The process capacities at the GTF have been arrived at by considering the needs of the group treatment participants within the park. Relatively small additional investment would allow process capacities to be increased so that the same facility could accept similar wastes from some of the very small job shops in the region, those which otherwise would be most severely impacted by the pretreatment regulations.

Each participant must carefully analyze his own operation and take steps to concentrate the wastes which he sends to the GTF. In the preceding analysis, it has been assumed that the flow rate of all running rinses would be minimized by installation of counter-current rinsing at all stations where this was calculated to be cost effective. In addition, careful sampling of all running rinses should be performed to determine which can go directly to the POTW without pretreatment. In place of, or in addition to counter-current rinses, still rinse installation prior to each running rinse should be evaluated. When the still rinse could not go directly to the sewer, the still rinse tank would be emptied into a storage tank to await shipment to the GTF. Of course, each plant should be certain that good housekeeping practices are in effect to minimize dragout, control spills, and recover plating bath solutions where possible.

Figure 6 shows the actions required by each of the plants which are able to concentrate their wastewater sufficiently to ship it economically to the GTF. According to the preceding analysis, nearly all of the plants at Huntington Industrial Park fall into this category. Those plants which, even after flow

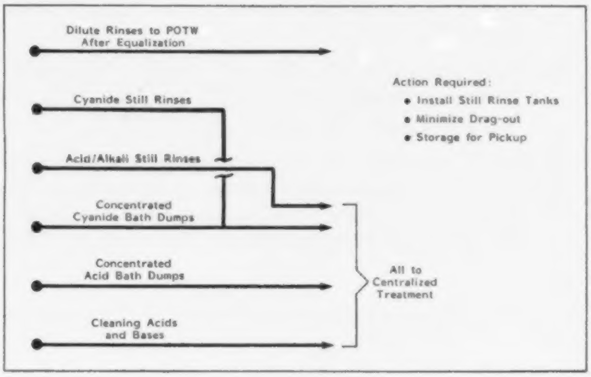
Dilute Rinses to POTW
After Equalization
Cyanide Still Rinses
Acid/Alkali Still Rinses
Concentrated
Cyanide Bath Dumps
Concentrated
Acid Bath Dumps
Cleaning Acids
and Bases
Action Required:
• Install Still Rinse Tanks
• Minimize Drag-out
• Storage for Pickup
All to
Centralized
Treatment

Figure 6.

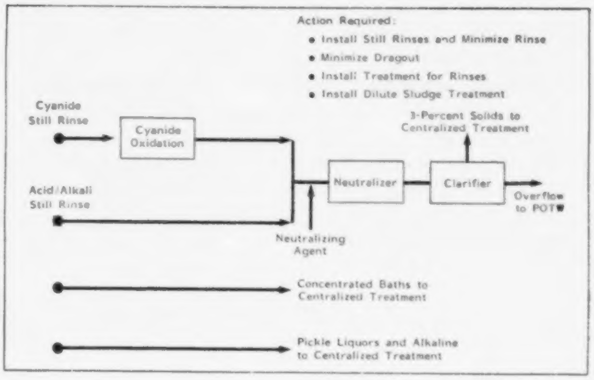
Action Required:
• Install Still Rinses and Minimize Rinse
• Minimize Dragout
• Install Treatment for Rinses
• Install Dilute Sludge Treatment
Cyanide
Still Rinse
Cyanide
Oxidation
3-Percent Solids to
Centralized Treatment
Acid/Alkali
Still Rinse
Neutralizer
Clarifier
Overflow
to POTW
Neutralizing
Agent
Concentrated Baths to
Centralized Treatment
Pickle Liquors and Alkaline
to Centralized Treatment

Figure 7.

minimization, still could not afford to ship their wastewater to the GTF, would exercise the option shown in Figure 7, involving some in-plant treatment with dilute sludge shipped to the GTF. This option may apply to one or two of the plants within the park, although, with maximum attention to flow reduction, it is believed likely that those plants would also send all of their wastewater requiring treatment to the GTF.

The capital required has been estimated as $300,000 to $800,000. The SBA Pollution Control Financing Guarantee Program is very attractive for such amounts, particularly when combined with an issue of tax-exempt bonds. It is recommended that the Huntington Industrial Park participants contact the SBA Office of Special Guarantees, an experienced underwriter, and the R.I. Department of Economic Development to explore this financing option.

The Group Treatment Facility at Huntington Industrial Park would require a permit from the State of Rhode Island authorizing it to operate as Hazardous Waste Treatment Facility. Truck hauling of the wastewater would be required to comply with applicable regulations concerning the transport of hazardous wastes. The GTF will, in addition, be faced with the cost of disposing of the dewatered sludge in an environmentally safe manner, in an approved hazardous material landfill (assuming that such sludges are classified as hazardous). These costs were not considered in the earlier analysis of savings to be achieved through group treatment, since the same costs, proportionately, would have to be borne by the participants were they to choose to treat their wastes individually. The GTF may, in fact, effect some savings here since it would be shipping to the landfill by 20 cubic yard truck loads rather than by the drum. One of the first actions to be undertaken by the participants should be identification of an ultimate disposal site and the associated costs, since no approved hazardous material disposal site exists within the State of Rhode Island.

This preliminary analysis has illustrated the considerable potential of the group treatment concept for reducing the costs of pretreatment to the industrial park participants. As has been noted, the proposed facility also has potential for service to a wider community, offering small plating job shops a means of complying with regulations while minimizing economic impact. The GTF costs and savings presented here have been based on operation of the facility on a two-shift basis. Additional capacity to treat wastes from outside the park could be gained by going to three-shift operation. Or, the initial facility design could be resized based on single shift operation, providing considerable room to increase operating hours and to process additional wastes.

The next phase of the work required to bring a project such as this to fruition should include, in addition to definition of the financing obtainable, detailed engineering design. This would include site selection and layout, treatment process specification and layout, transportation system and/or piping system design, detailed capital and operating cost estimates, leading to working drawings and specifications. Resource recovery at the GTF should be evaluated and included in the design if economic. Detailed engineering design coupled with firm financing plans will allow accurate projection of the costs to each participant.

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